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MULTIPLE-PLATE MODIFICATION OF QUICKE2 ANALYTICAL ELECTRON EMISSION CODE

IRT Corporation

P.O. Box 80817

San Diego, California 92138

15 July 1976

Topical Report for Period 8 September 1975—15 July 1976

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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QUICKE2 Computer Code	
Photon Attenuation	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report examines the performance of the QUICKE2 source code, authored by T.A. Dellin and C.J. MacCallum of Sandia Laboratories. The version referred to in this report contains an IRT modification to accommodate photon attenuation and electron emission for multiple layers. Numerous comparisons are made of QUICKE2 calculations with other computer codes and with experiments for a variety of conditions. Information of a practical nature, necessary for modeling problems with the code, is provided. Specific input requirements are listed and outputs are interpreted by means of a sample problem.

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18.   SUPPLEMENTARY NOTES (Continued)

NOTE

To distinguish between this modified version of QUICKE2
and the unmodified QUICKE2, it is requested that future
references to the modified version described herein use
the name "QUICKE2M".

ACCESSION for

NTIS   White Section ☑
DDC   Buff Section   ☐
UNANNOUNCED   ☐
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A

1. INTRODUCTION

QUICKE2 (Ref 1) is an analytical computer code which calculates bulk and vacuum emission currents produced when materials are subjected to x-rays. This code was developed by T. A. Dellin and C. J. MacCallum of Sandia Laboratories in 1974. As a refinement of earlier QUICKE2 versions, it has seen extensive use in the radiation effects community since its initial release. This report is intended as a descriptive extension to Reference 1. It reviews in some detail the analytical models used in the code, input/ output requirements, and compares its solutions with the results from other codes as well as with relevant experimental data. The version examined in this document contains an IRT extension to the original QUICKE2 subroutines that permits the application of QUICKE2 to multiple-plate geometries. The calculations are carried out in a single computer run for a given spectrum and plate combination, and are expedited by the user-oriented features of simple free-field input formats and versatile output plot capabilities. These and other code features are described in detail in the remainder of this report.

Documentation is divided into sections as follows.

Section 2 Description of the Physics

3 Comparison of QUICKE2 with Other Codes and Experiments

4 Description of the Input

5 Sample Problem and Output Description

6 Computer Requirements

A summary of the capabilities and limitations of QUICKE2 and its multiple-plate extension is shown.

N R

1. T. A. Dellin and C. J. MacCallum, "QUICKE2: A One-Dimensional Code for Calculating Bulk and Vacuum Emitted Photo-Compton Currents," Sandia Laboratories, SLL-74-0218, April 1974.

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Physical Modeling:

Geometry	Infinite plates
Materials available	25 elements, $1 \leq Z \leq 92$
Number of elements per plate	≤ 8
Number of plates	No limit
Photon energy range	1 keV to 10 MeV
Photon angle of incidence	0 to 180° measured from surface normal of each plate
Typical outputs	Photon spectra, electron spectra, and angular distributions and yields

Calculational Considerations:

Computer time requirements	20 to 60 sec 7600 CPU per electron emission spectrum
Number of energy groups per spectrum	Photons: 50
	Electrons: 34

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2. DESCRIPTION OF THE PHYSICS

A review of the physics employed in QUICKE2 is given in this section. Extensive descriptions of the formulation are given by Dellin and MacCallum in Reference 1.

QUICKE2 physics can be divided conveniently into the categories of photon attenuation, electron creation, and electron transport. Highlights of each segment are listed below.

2.1 PHOTON ATTENUATION

QUICKE2 calculates the attenuation of photon beams passing through materials, assuming that the flux decreases exponentially at the distance penetrated for each energy bin. Compton-scattered photons and other secondary photons are neglected. The energy-dependent attenuation lengths are taken from the tables of Biggs and Lighthill (Ref 2).

The calculation proceeds as follows. A photon spectrum is input into QUICKE2 as a set of coordinates (dN/dE or dE/dE, E). In addition, the composition and thickness of one or more attenuating layers is specified. For materials of one element, an attenuation length λ_E is interpolated from the tables for each photon energy E. The number of photons of energy E that leave the material is then calculated as the incident number times the attenuation factor $[\exp(-\tau/\lambda_E)]$, where τ is the thickness of the material. For materials of two or more elements, the photons are assumed to pass through a series of monoelemental layers of thickness $f_i\tau$, where f_i is the fraction by weight of the $i\underline{th}$ element of the compound and τ is the thickness of the compound in g/cm^2. The number of photons of energy E leaving the material is then taken as the incident number times the attenuation factor $[\exp(-\Sigma_i f_i/\lambda_{Ei})\tau]$.

2. G. L. Simmons and J. H. Hubbell, "Comparison of Photo-Interaction Data Set VII. Biggs-Lighthill (Rev.) and ENDF/B," NBSIS 73-241, July 1973.

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Except near the photoelectric edges, log-log interpolation of the cross sections taken from the tables is accurate since the intervals between photoelectric edge energies are closely approximated by line segments for a log-log plot of cross-section versus photon energy. If an interval between two tabulated points contains both a spectral energy E and a photoelectric edge, the relationship of E to the edge energy is determined and the cross-section is interpolated accordingly.

The tabulated cross-sections include photoelectric absorption, coherent and incoherent scattering, and pair production. All of these processes are considered to remove photons from the incident beam. For photon energies relevant to QUICKE2 (1 keV to 10 MeV), the error introduced by including coherent scattering in the absorption cross section is small since this process is dominated by the photoelectric effect at low energies and by incoherent (→ Compton) scattering at high energies.

2.2 ELECTRON CREATION AND TRANSPORT

Electron creation in QUICKE2 is due to Compton, photoelectric, and Auger processes occurring more than an extrapolated electron range away from any material interface. Photon energies from 1 keV to 10 MeV can be specified. Electron emission due to a spectrum of photon energies is obtained by superposition of emissions from monoenergetic photons.

Electron angle and energy distrubtion functions for the bulk material are obtained from exact solutions to the transport equation. They are exact only for the regions of the target that are further than an extrapolated electron range from the material interfaces. Distribution functions for electrons emerging from infinite slabs of materials into vacuum are obtained from these exact bulk solutions using interpolative approximations. Complete emission electron energy and angular distributions can be obtained for normal photon incidence, and for non-normal photon sources with azimuthal symmetry. Angle-integrated spectra are available for other non-normal photon incidences.

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3. COMPARISON OF QUICKE2 WITH OTHER CODES AND EXPERIMENT

QUICKE2 calculations of electron emission are compared with those of other codes and with experiment in this section. Specific comparisons are made to the SANDYL, POEM, GRAP2, and ETRAN codes (Refs 3-6) and to the experiments of Barlett and Weingart (Ref 7), Bradford (Ref 8), Denison et al (Ref 4), and Ebert and Lauzon (Ref 9). Photon attenuation results compared to those of the FHUFF code (Ref 10).

Table 3-1 contains total reverse yields from Aℓ, Cu, and Ta for a 50-keV bremsstrahlung spectrum as measured by Bradford and as calculated by the POEM, SANDYL, and QUICKE2 codes. This table is adapted from Reference 7.

Table 3-2 contains forward and reverse yields for 5-, 10-, and 15-keV blackbody spectra incident on 40 mils of Aℓ as calculated by SANDYL and QUICKE2.

Figures 3-1 through 3-3 show energy distributions of the back-emitted electrons for the Bradford experiments and for QUICKE2.

3. H. M. Colbert, "SANDYL: A Computer Program for Calculating Combined Photon-Electron Transport in Complex Systems," Sandia Laboratories, SLL-74-0012 (1974).

4. W. L. Chadsey, "A Monte Carlo Photo-Current/Photo-Emission Computer Program," National Symposium on Natural and Man-Made Radiation in Space, Las Vegas, March 1971.

5. E. P. Wenaas and M. Williams, "GRAPUP: A Computer Code for Secondary Electron Emission from Plates," Gulf General Atomic, GAMD-10155, June 1970.

6. "ETRAN: Monte Carlo Code System for Electron and Photon Transport Through Extended Media," NBS reports 9836 and 9837.

7. C. J. MacCallum and T. A. Dellin, J. Appl. Phys. 44, 1878 (1973).

8. J. N. Bradford, "Radiation-Induced Electron Emission," AFCRL-TR-74-0583, November 1974.

9. P. Ebert and A. Lauzon, "Measurement of Gamma-Ray-Induced Secondary Electron Current from Various Elements," IEEE Trans. Nucl. Sci. NS-13, p. 735 (1966).

10. M. J. Nowak, M. R. White, and J. P. Wondra, "The FHUFF Code for X-Ray Energy Deposition with Fluorescent Heating and Fluorescent Fluxes, Gulf General Atomic, GAMD-9463, July 1969.

Figures 3-4 through 3-6 give energy distributions for reverse emission from Aℓ, Ti, and Fe as measured by Denison et al. and as calculated by POEM and QUICKE2. Because the absolute yields for the experiment and POEM were not available, the curves were normalized to the same electron number densities as the QUICKE2 results at the peaks of either the K-photo edge or L-Auger contribution, whichever was greater. QUICKE2 yields are given on the figures, and various contributions to the electron spectra are labeled. These figures are adapted from Reference 4.

Figures 3-7 through 3-10 show the reverse and forward cumulative emission spectra from typical satellite materials for 2-, 5-, 10-, and 15-keV blackbody photon spectra as calculated by GRAP2 and QUICKE2. The reverse emission is from a quartz solar cell cover, while the forward emission is into an aluminum equipment box. The incident spectra used in the latter calculations are the blackbody spectra filtered through a typical solar cell and through the wall of the box, as shown in Figure 3-11. In these instances, the ordinate label "per calorie" always means "per calorie incident on the front face of the solar cell."

In Figures 3-12 through 3-15, photon attenuation predicted by the subroutine ATTEN is compared to FHUFF calculations for the cases of Figures 3-7 through 3-10. Here, the photon spectra are also compared as they leave the solar cell before entering the aluminum box. The quantity plotted is the cumulative fluence of photons with energy less than the energy indicated on the abscissa. Very minor differences are seen in the results.

For a hard-spectrum comparison, the forward and reverse yields and the forward angular distributions calculated by QUICKE2 are compared to the experimental results of Ebert and Lauzon for 1.25-MeV photons incident on thick targets of C, Aℓ, Cu, and Pb. The results are summarized in Table 3-3 and in Figures 3-16 through 3-19. Note that, while the forward yields obtained by the two methods agree well, the QUICKE2 angular distributions are not as sharply peaked at $\theta = 0$ as the experimental ones. Figure 3-20, taken from Reference 7, shows Dellin and MacCallum's comparison of QUICKE2 with the Ebert-Lauzon experiment and with the Monte Carlo code SANDYL. Their results are in units of electrons per unit angle rather than electrons per unit solid angles, emphasizing the fact that the solid

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angle approaches zero as Θ approaches zero. Since this form is indicative of real spatial emission, the discrepancies in the results at small angles shown in Figures 3-16 through 3-19 probably have minor impact on calculations employing QUICKE2 electron emission data. The results in Table 3-1 through 3-3 and Figures 3-1 through 3-6 indicate that the QUICKE2 calculations agree quite well with SANDYL and POEM Monte Carlo calculations and with the experimental data of Bradford. The largest differences were for reverse emission due to low energy photons (Table 3-2) but the discrepancies were less than a factor of two.

Table 3-1

QUICKE2 RESULTS COMPARED WITH EXPERIMENT AND OTHER
CALCULATIONS FOR REVERSE YIELDS FROM DIFFERENT MATERIALS[a]
(Photons from 50-keV bremsstrahlung)

	Aℓ	Cu	Ta
Bradford Experiment (AFCRL)	1.9×10^{-7}	4.8×10^{-7}	1.2×10^{-6}
QUICKE2	1.5×10^{-7}	3.6×10^{-7}	1.0×10^{-6}
SANDYL	1.5×10^{-7}	3.2×10^{-7}	8.7×10^{-7}
POEM	1.5×10^{-7}	3.3×10^{-7}	8.8×10^{-7}

[a]From Ref. 7.

Table 3-2

QUICKE2 RESULTS FOR FORWARD AND REVERSE YIELDS
FROM Aℓ COMPARED WITH SANDYL FOR DIFFERENT SPECTRA
(Plate thickness 40 mils)

	5-keV BB	10-keV BB	15-keV BB
Reverse			
QUICKE2	3.4×10^{-7}	9.2×10^{-8}	3.9×10^{-8}
SANDYL	2.3×10^{-7}	6.6×10^{-8}	2.8×10^{-8}
Forward			
QUICKE2	2.9×10^{-8}	2.9×10^{-8}	2.0×10^{-8}
SANDYL	3.4×10^{-8}	3.1×10^{-8}	1.7×10^{-8}

5-, 10-, and 15-keV blackbody spectra are incident.
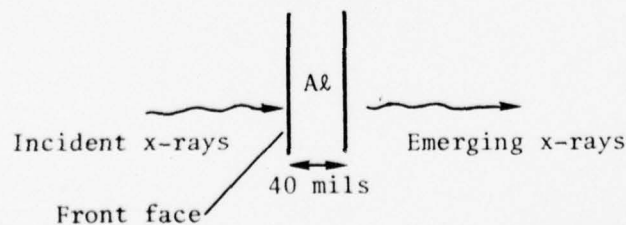All yields are in C/cal incident on front face of Aℓ.

Incident x-rays → Aℓ → Emerging x-rays

Front face / 40 mils

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Table 3-3

QUICKE2 AND EXPERIMENTAL RESULTS COMPARED FOR HIGH-ENERGY PHOTONS

Material	Thickness (g/cm^2)	Experiment of Ebert & Lauzon	QUICKE2
Forward Yields[a]			
Carbon	0.457	3.0×10^{-8} (9.1×10^{-3})	2.8×10^{-8} (8.4×10^{-3})
Aluminum	0.614	2.7×10^{-8} (8.0×10^{-3})	2.3×10^{-8} (7.0×10^{-3})
Copper	0.467	1.8×10^{-8} (5.3×10^{-3})	1.8×10^{-8} (5.5×10^{-3})
Lead	0.591	2.0×10^{-8} (6.1×10^{-3})	1.7×10^{-8} (5.3×10^{-3})
Reverse Yields[a]			
Carbon		1.1×10^{-9} (3.4×10^{-4})	1.2×10^{-9} (3.6×10^{-4})
Aluminum		1.1×10^{-9} (3.3×10^{-4})	2.2×10^{-9} (6.6×10^{-4})
Copper		4.3×10^{-9} (1.3×10^{-3})	3.7×10^{-9} (1.1×10^{-3})
Lead		7.3×10^{-9} (2.2×10^{-3})	7.4×10^{-9} (2.2×10^{-3})

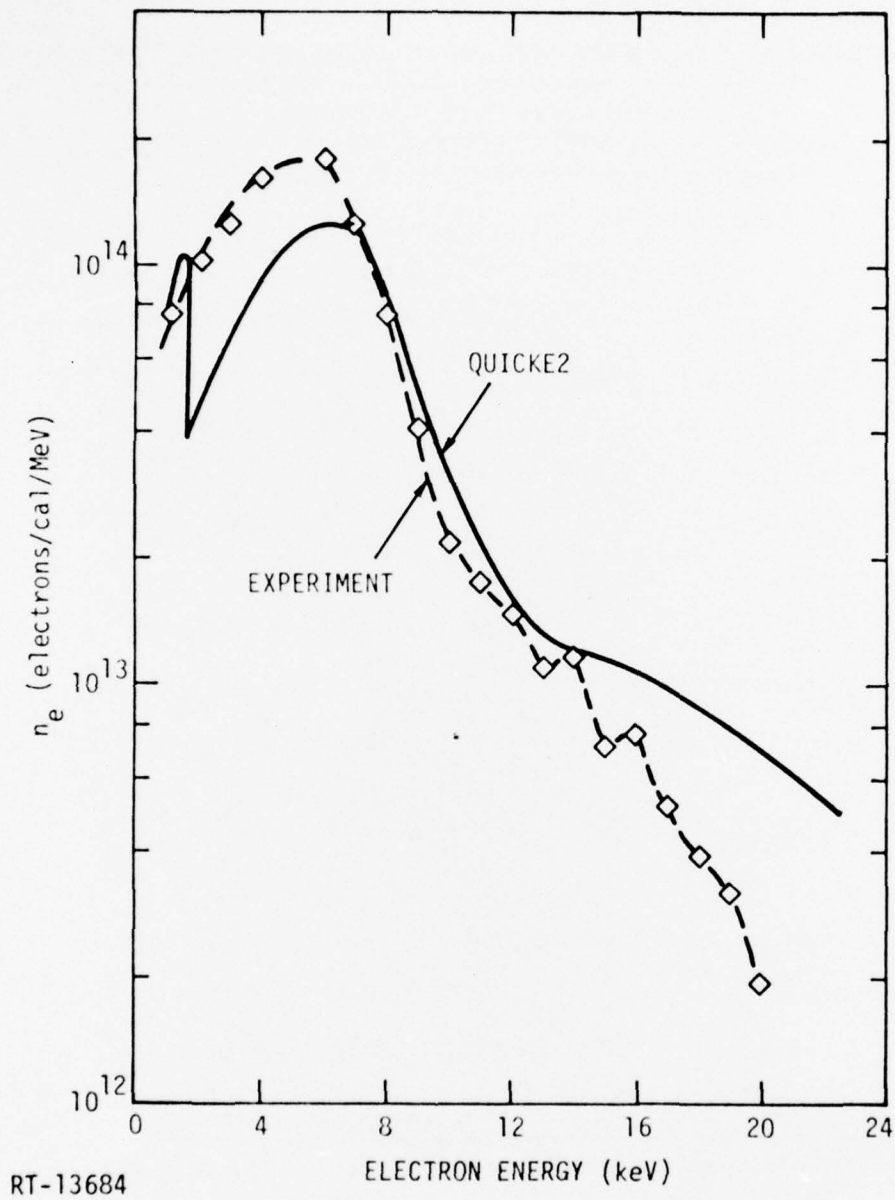[a]Yields without parentheses are in C/cal; yields in parentheses are in electrons/photon.

Figure 3-1. QUICKE2 results compared with experimental results
of Bradford for reverse-emitted electron energy
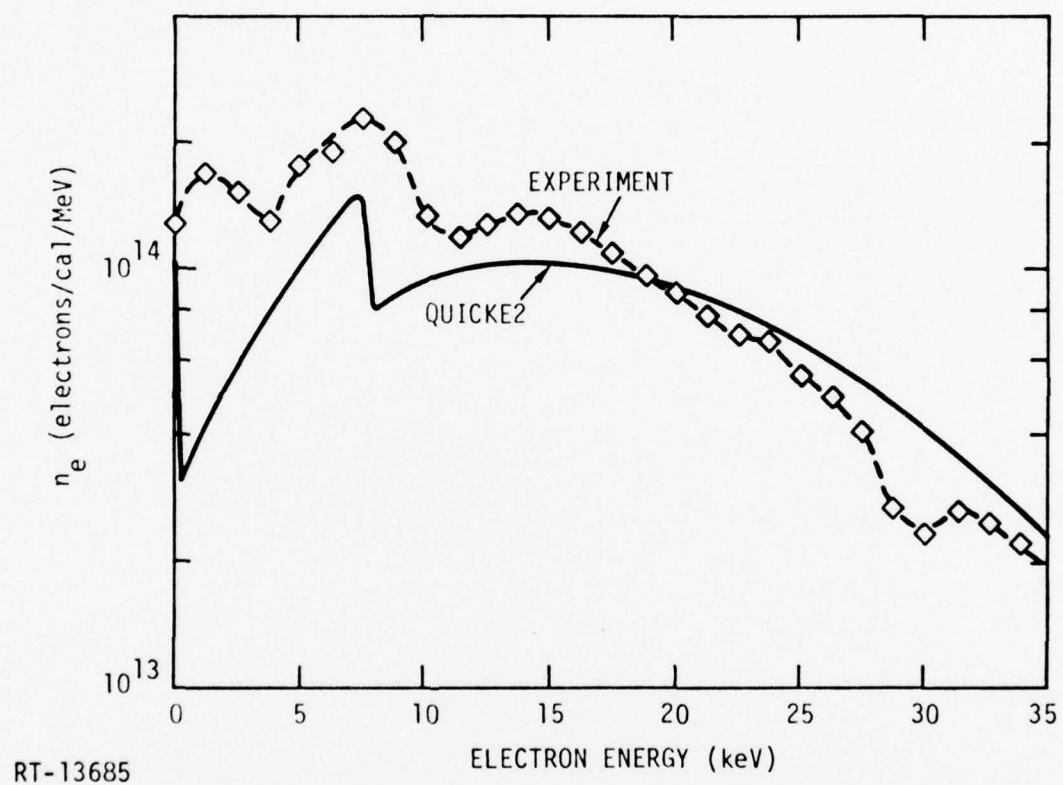spectra obtained from 50-keV bremsstrahlung on Aℓ

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RT-13685

Figure 3-2. QUICKE2 results compared with experimental results
of Bradford for reverse-emitted electron energy
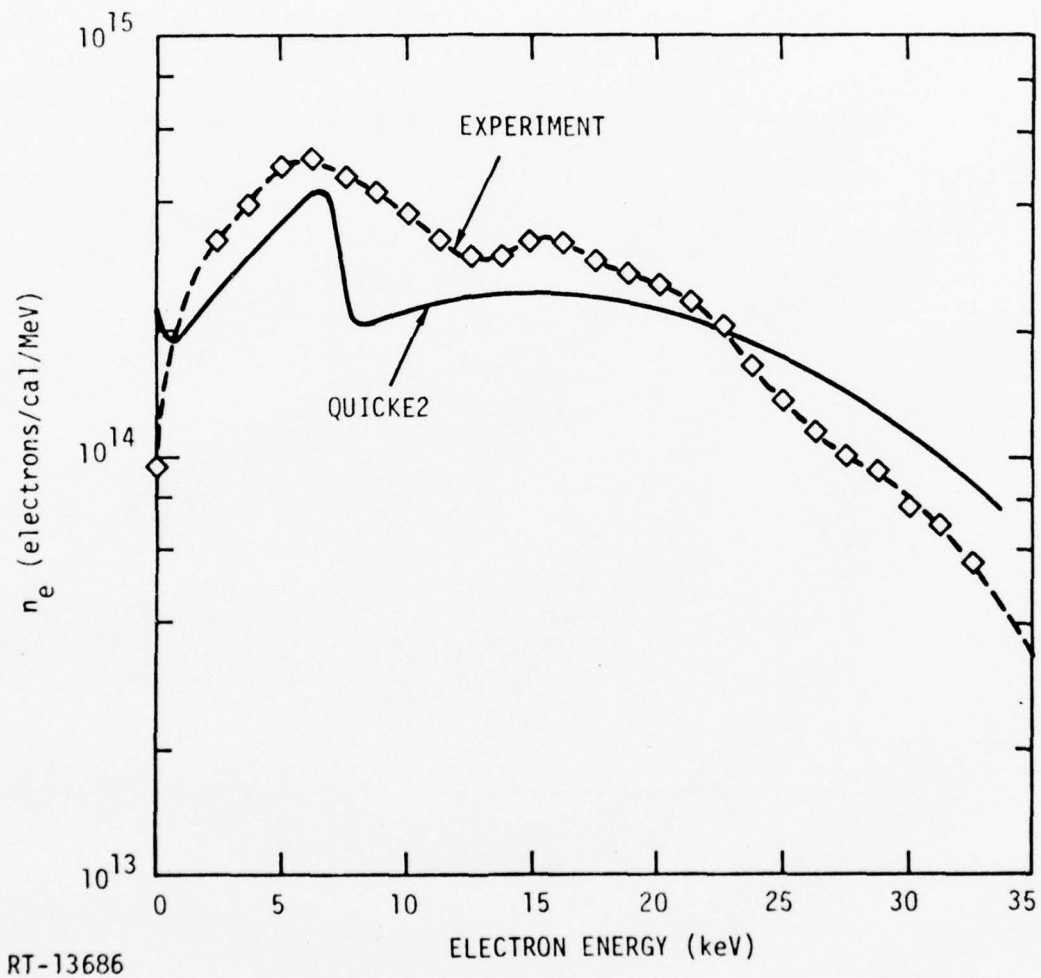spectra obtained from 50-keV bremsstrahlung on Cu

11

Figure 3-3.   QUICKE2 results compared with experimental results
of Bradford for reverse-emitted electron energy
spectra obtained from 50-keV bremsstrahlung on Ta

RT-13686

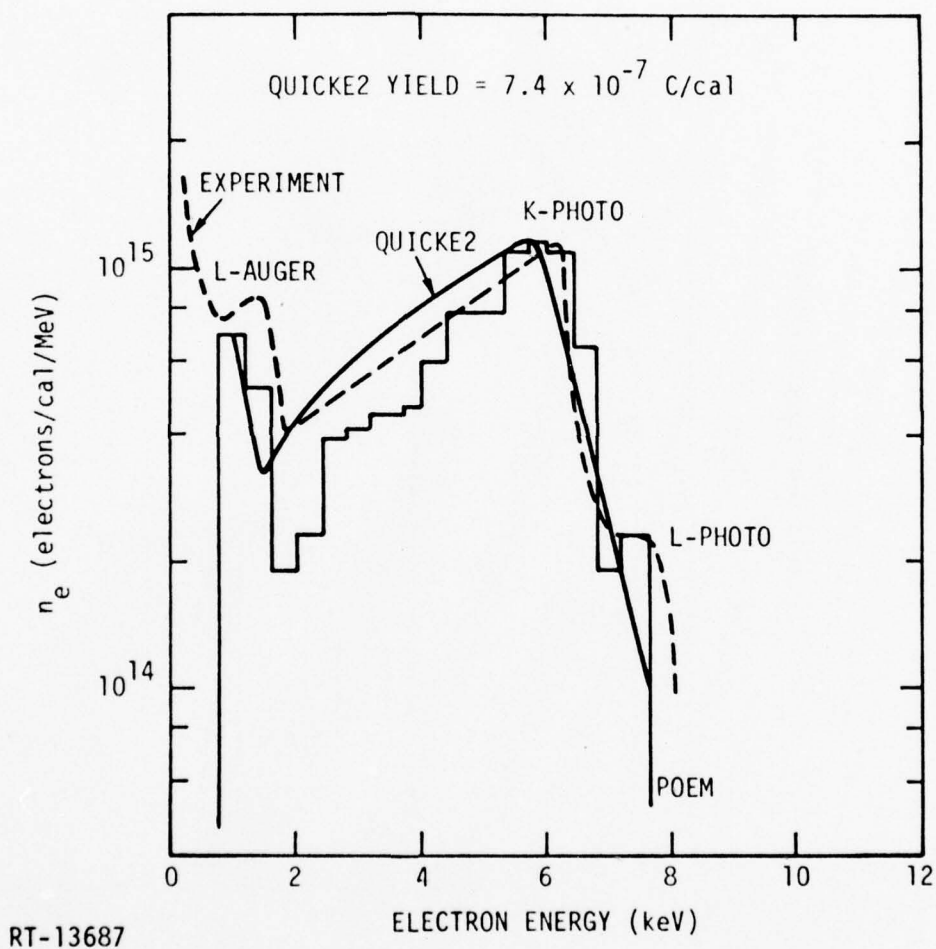12

QUICKE2 YIELD $= 7.4 \times 10^{-7}$ C/cal

Figure 3-4. QUICKE2 reverse-emitted electron energy distribution
compared with POEM code and experimental results of
Denison et al. for 8-keV monoenergetic photons inci-
dent on Aℓ; curves normalized to same heights at
K-photo edge peaks

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QUICKE2 YIELD = 3.0×10^{-6} C/cal
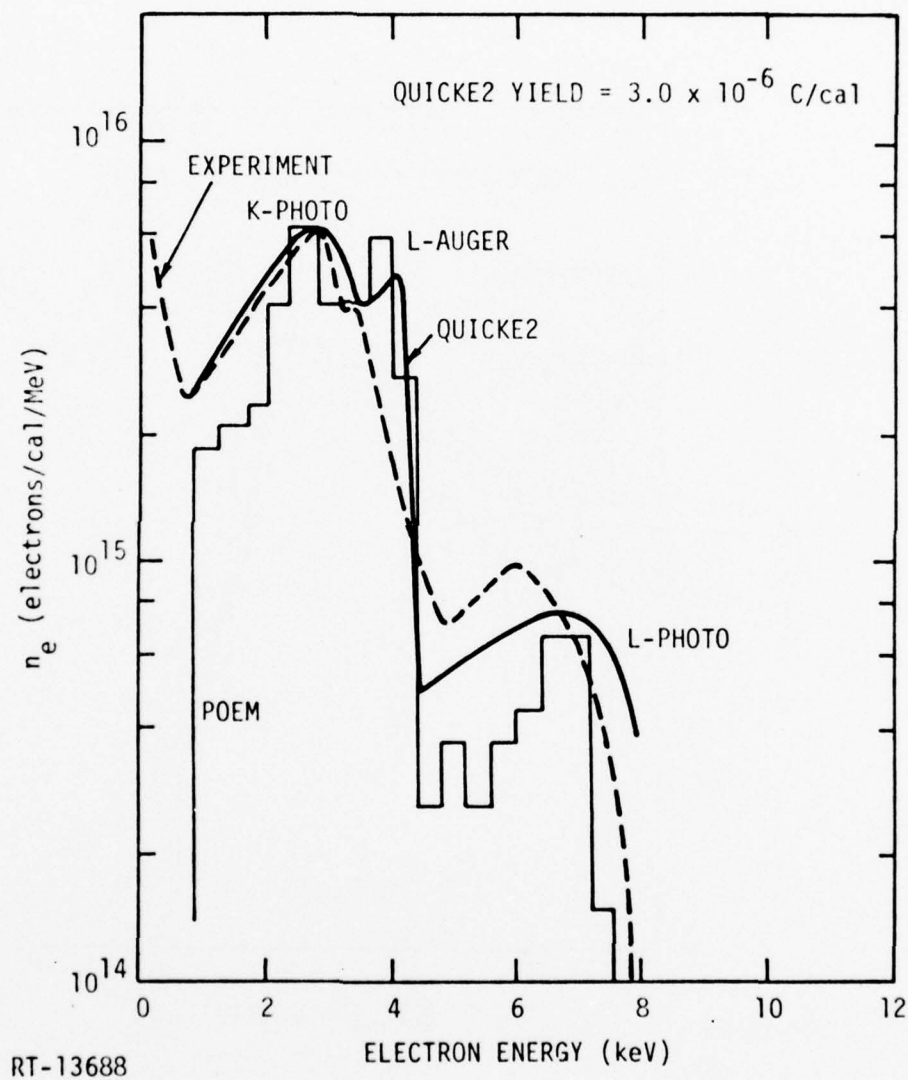
RT-13688

Figure 3-5. QUICKE2 reverse-emitted electron energy distribution
compared with POEM code and experimental results of
Denison et al. for 8-keV monoenergetic photons inci-
dent on Ti; curves normalized to same heights at
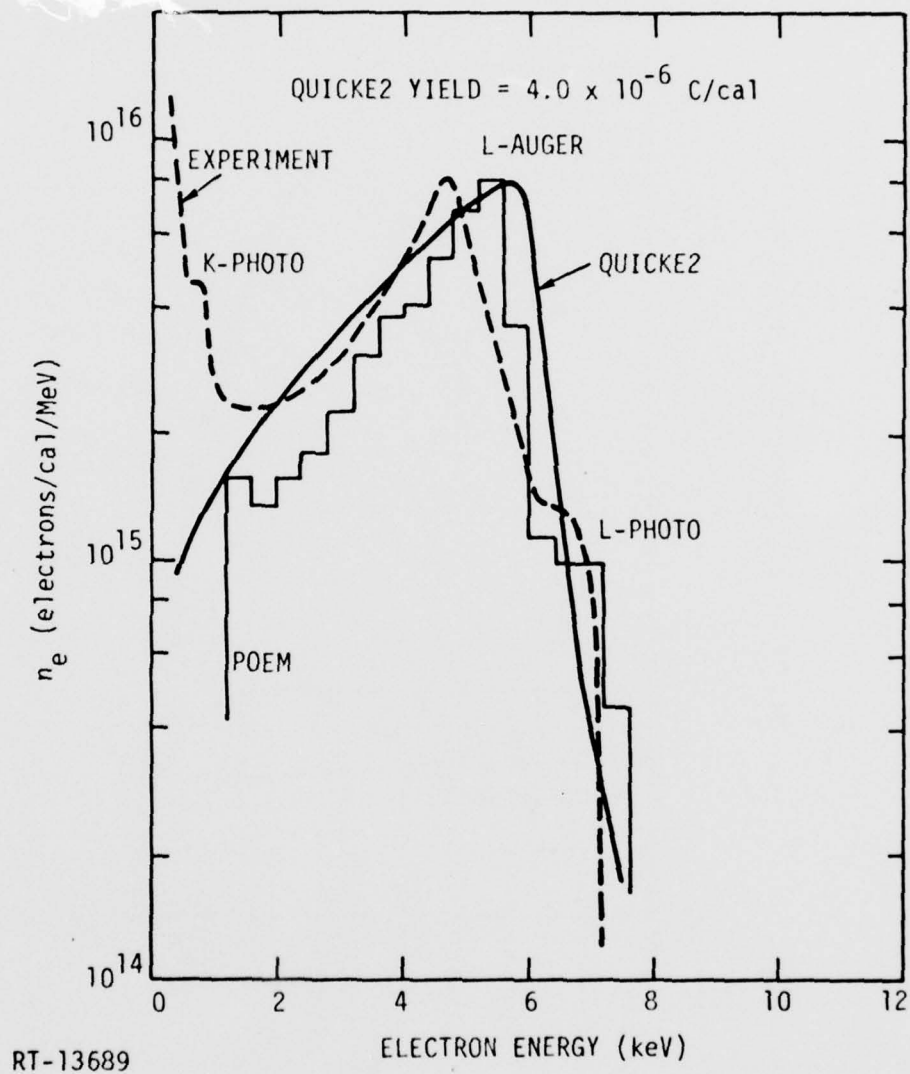K-photo edge peaks

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Figure 3-6. QUICKE2 reverse-emitted electron energy distribution
compared with POEM code and experimental results of
Denison et al. for 8-keV monoenergetic photons inci-
dent on Fe; curves normalized to same heights at
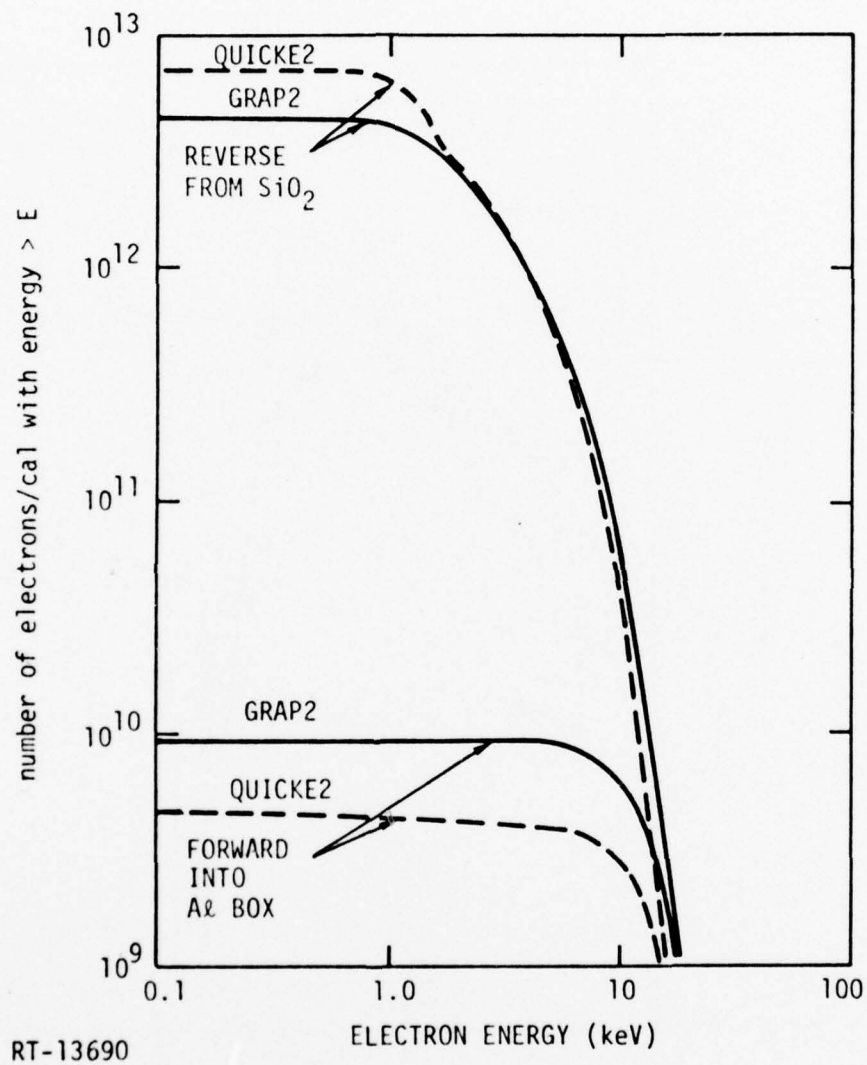L-Auger peaks

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Figure 3-7. Comparison of QUICKE2 and GRAP2 electron spectra for reverse emission from a solar cell cover and forward emission from Aℓ after attenuation by the solar cell; incident photon spectrum due to black-body radiator with temperature 2 keV

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Figure 3-8. Comparison of QUICKE2 and GRAP2 electron spectra for reverse emission from a solar cell cover and forward emission from Aℓ after attenuation by the solar cell; incident photon spectrum due to black-body radiator with temperature 5 keV
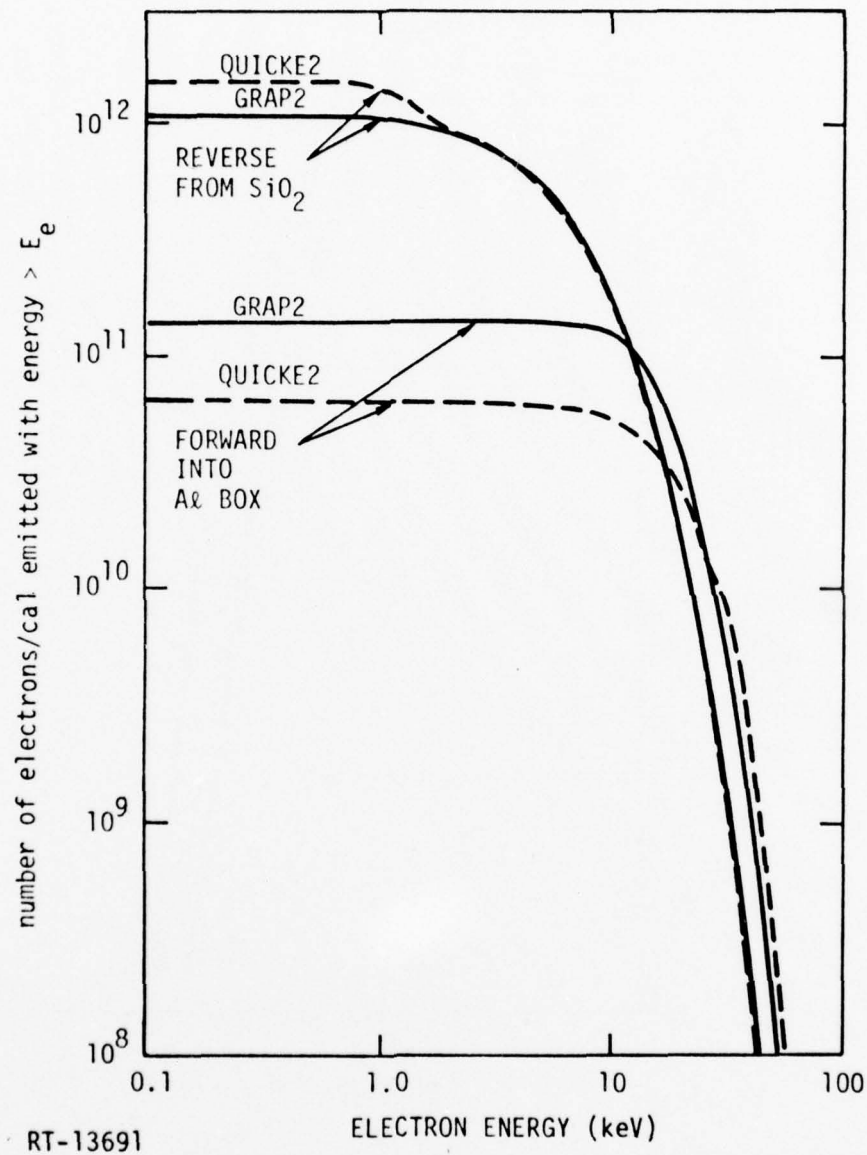
17

Figure 3-9. Comparison of QUICKE2 and GRAP2 electron spectra for reverse emission from a solar cell cover and forward emission from Aℓ after attenuation by the solar cell; incident photon spectrum due to black-body radiator with temperature 10 keV

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QUICKE2

GRAP2

FORWARD INTO Al BOX

10^{11}

GRAP2

REVERSE FROM SiO_2

QUICKE2

10^{10}

10^9

10^8

10^7

number of electrons/cal emitted with energy > E

ELECTRON ENERGY (keV)

1.0   10   100   1000

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Figure 3-10. Comparison of QUICKE2 and GRAP2 electron spectra
for reverse emission from a solar cell cover and
forward emission from Al after attenuation by the
solar cell; incident photon spectrum due to black-
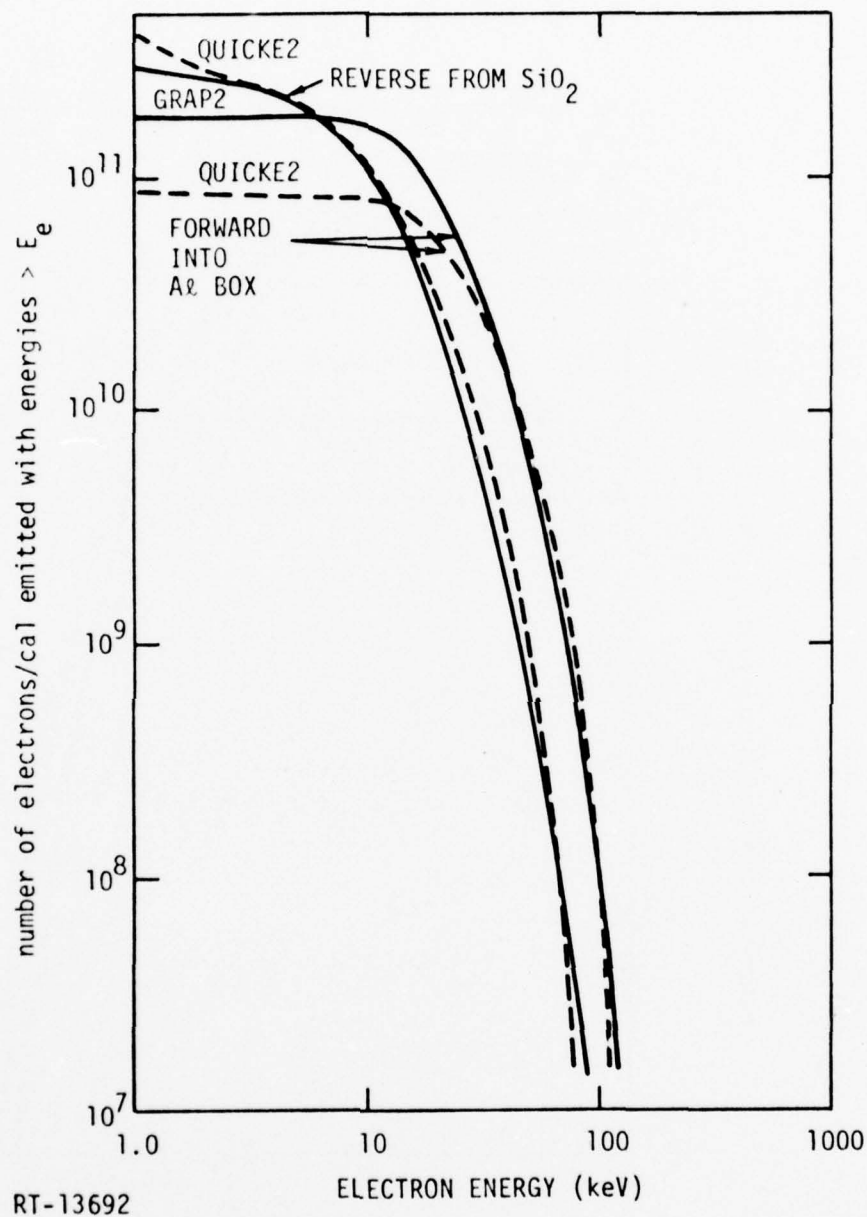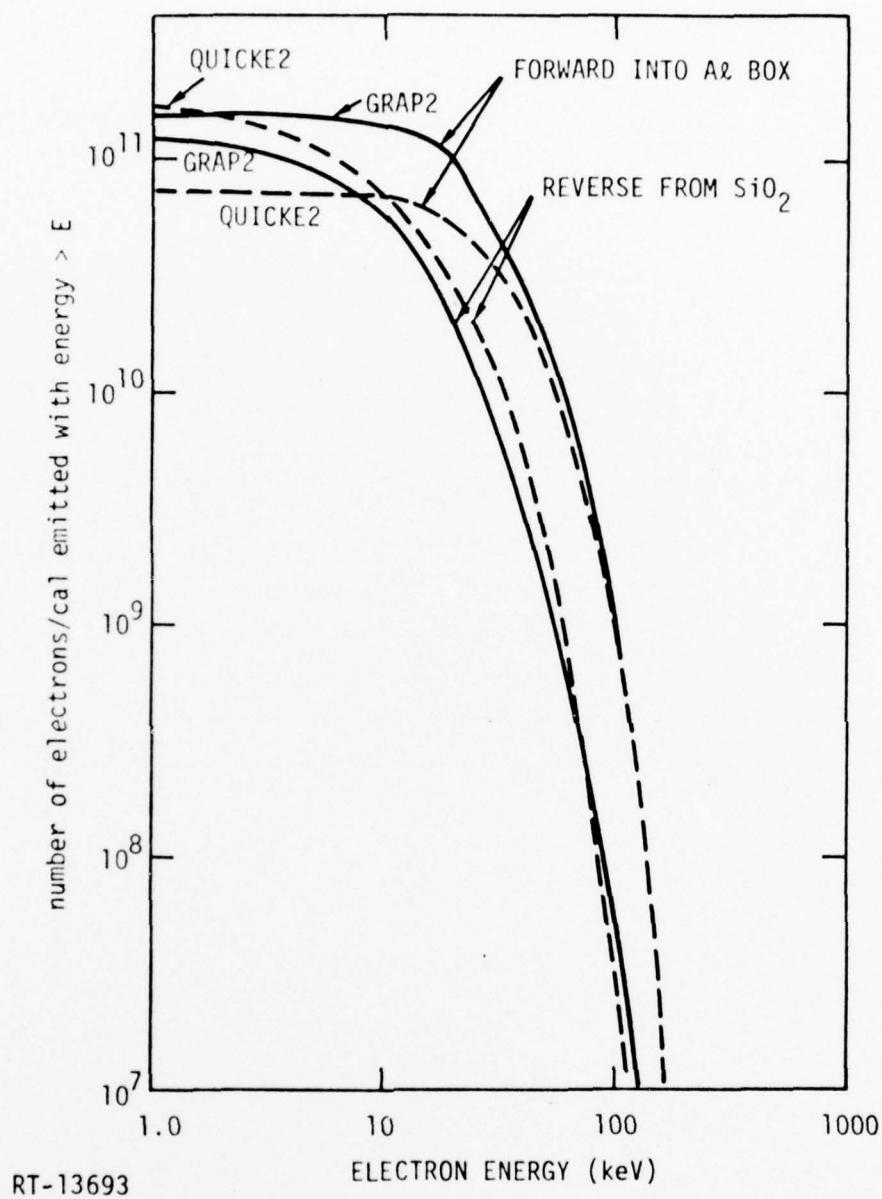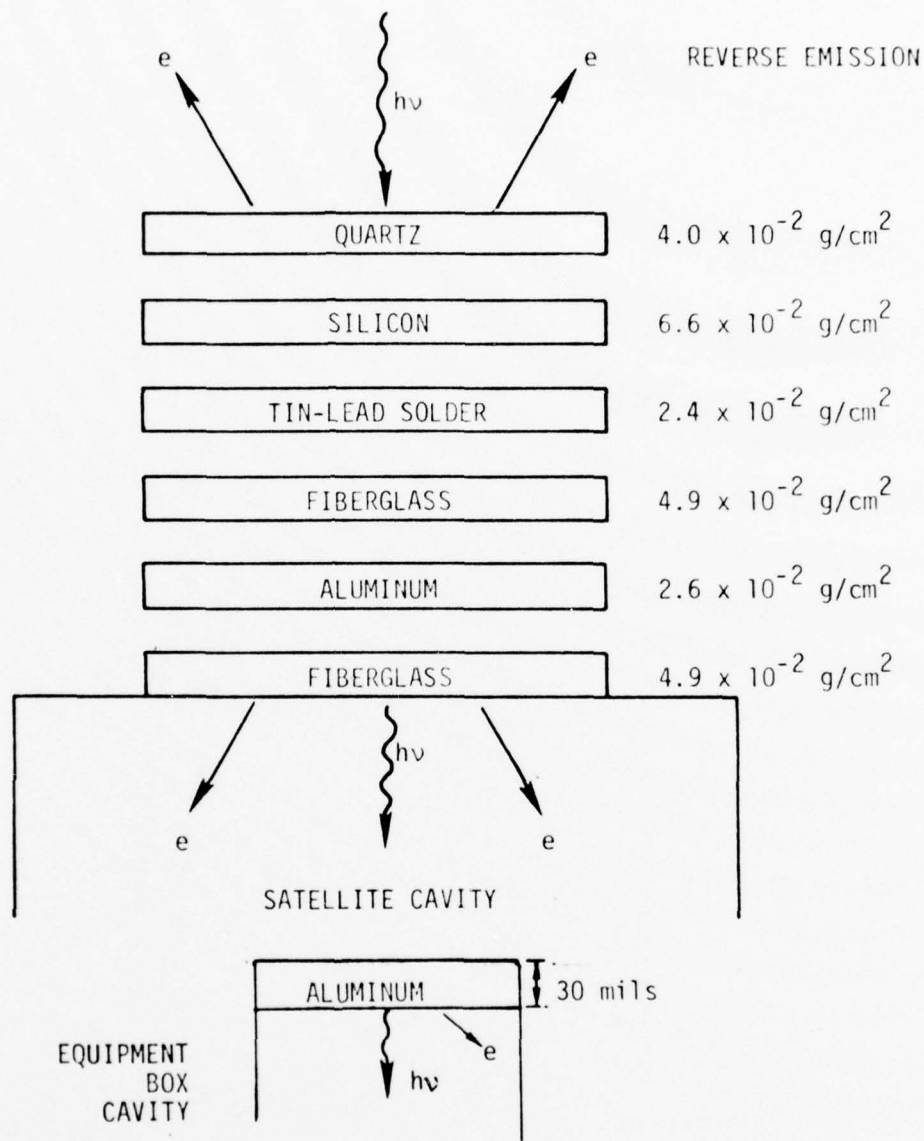body radiator with temperature 15 keV

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e $h\nu$ e   REVERSE EMISSION

QUARTZ	4.0×10^{-2} g/cm^2
SILICON	6.6×10^{-2} g/cm^2
TIN-LEAD SOLDER	2.4×10^{-2} g/cm^2
FIBERGLASS	4.9×10^{-2} g/cm^2
ALUMINUM	2.6×10^{-2} g/cm^2
FIBERGLASS	4.9×10^{-2} g/cm^2

e $h\nu$ e

SATELLITE CAVITY

ALUMINUM   30 mils

EQUIPMENT BOX CAVITY $h\nu$ e

RT-06431

Figure 3-11. Materials used in emission and attenuation calculations to represent typical satellite solar cell and equipment box cover. The QUICKE2 version described here performs the calculation with a single computer run.
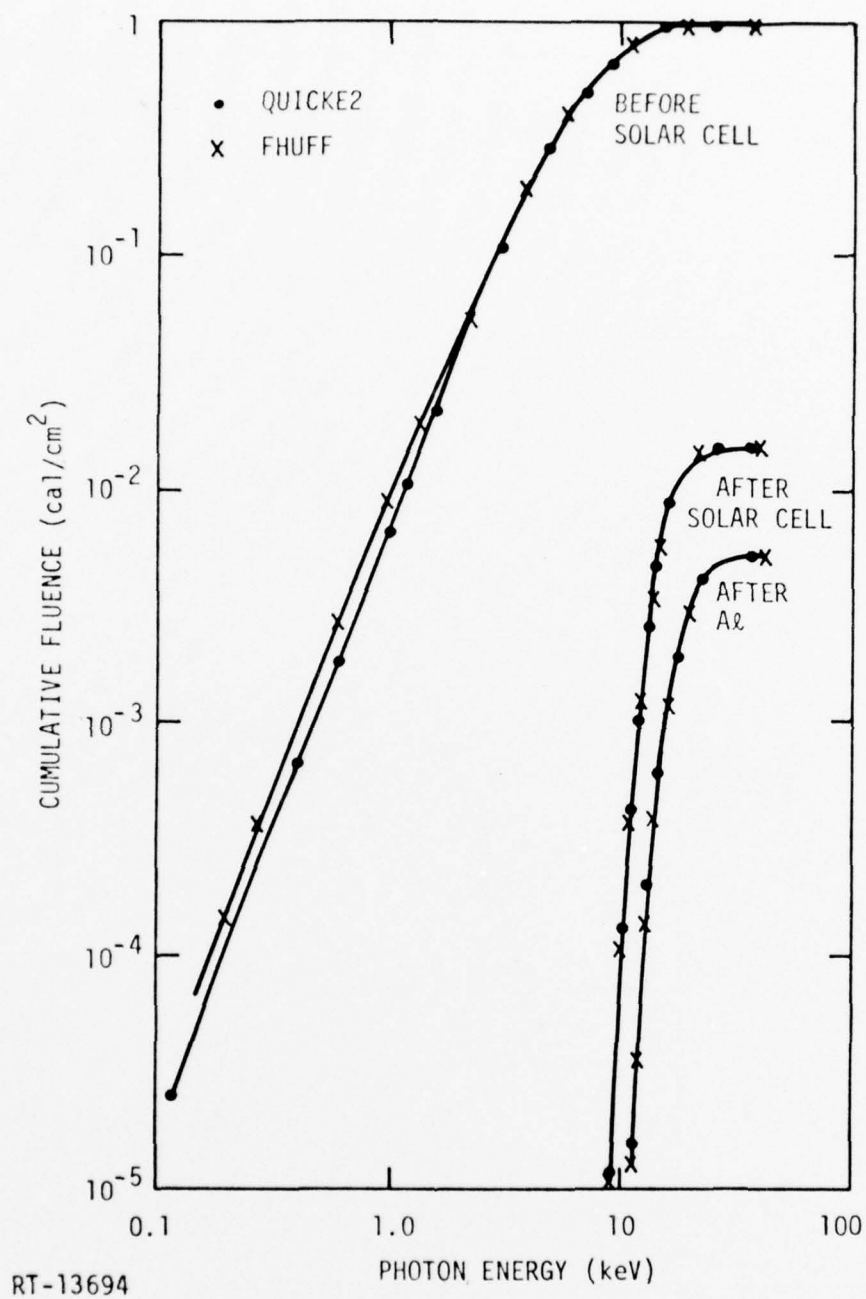
20

Figure 3-12. Comparison of QUICKE2 and FHUFF 2-keV blackbody
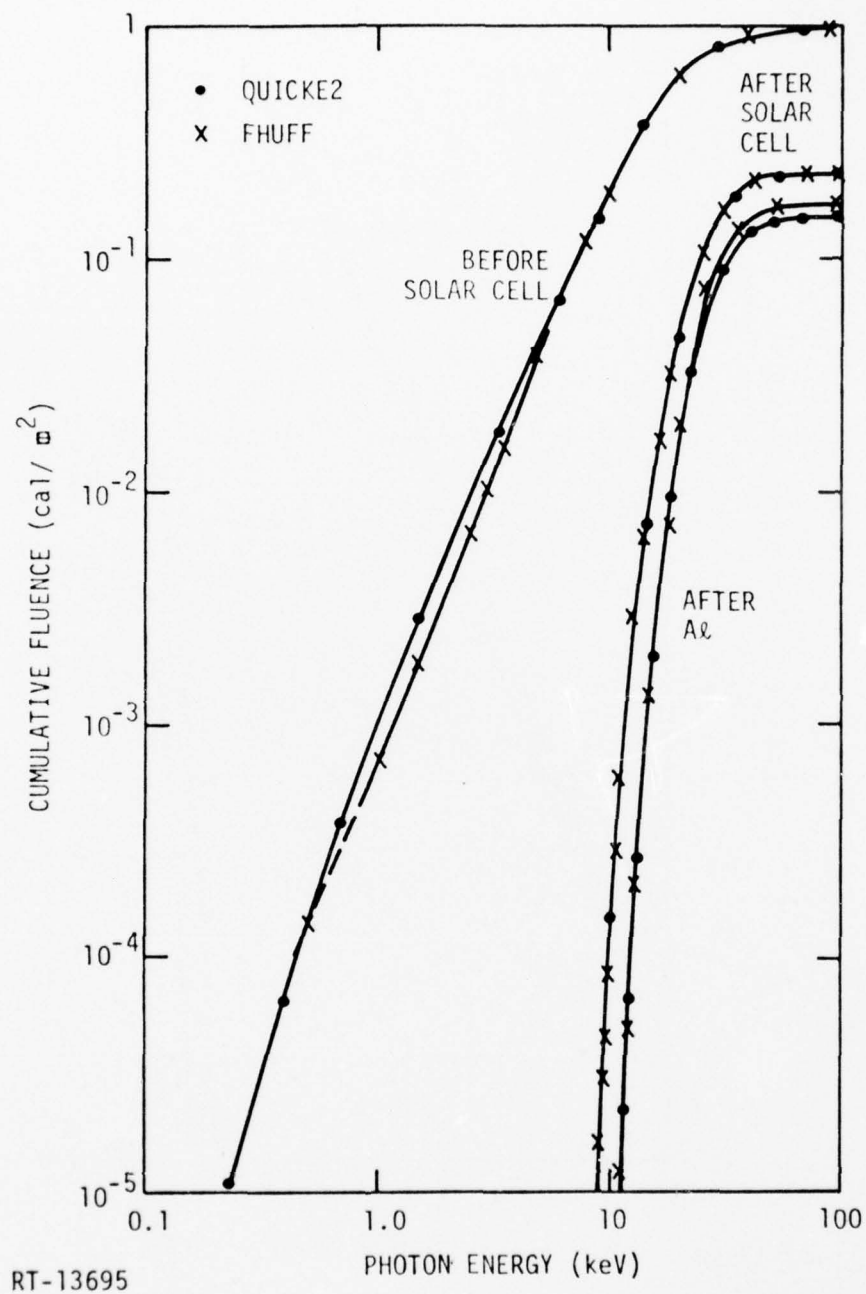photon spectra attenuated by solar cell and 30
mils of Aℓ

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Figure 3-13. Comparison of QUICKE2 and FHUFF 5-keV blackbody
photon spectra attenuated by solar cell and 30
mils of Aℓ

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Figure 3-14.   Comparison of QUICKE2 and FHUFF 10-keV blackbody
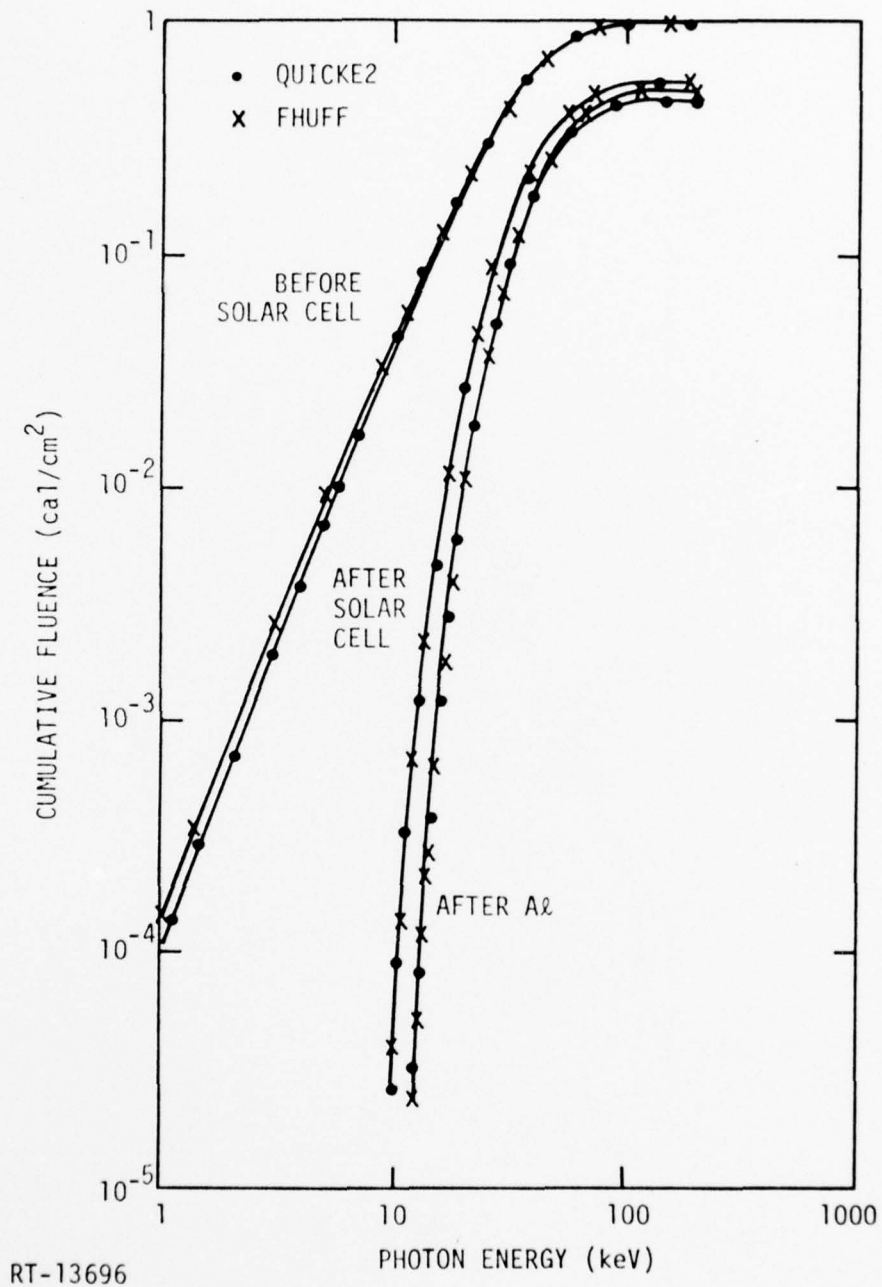photon spectra attenuated by solar cell and 30
mils of Aℓ

RT-13696

23
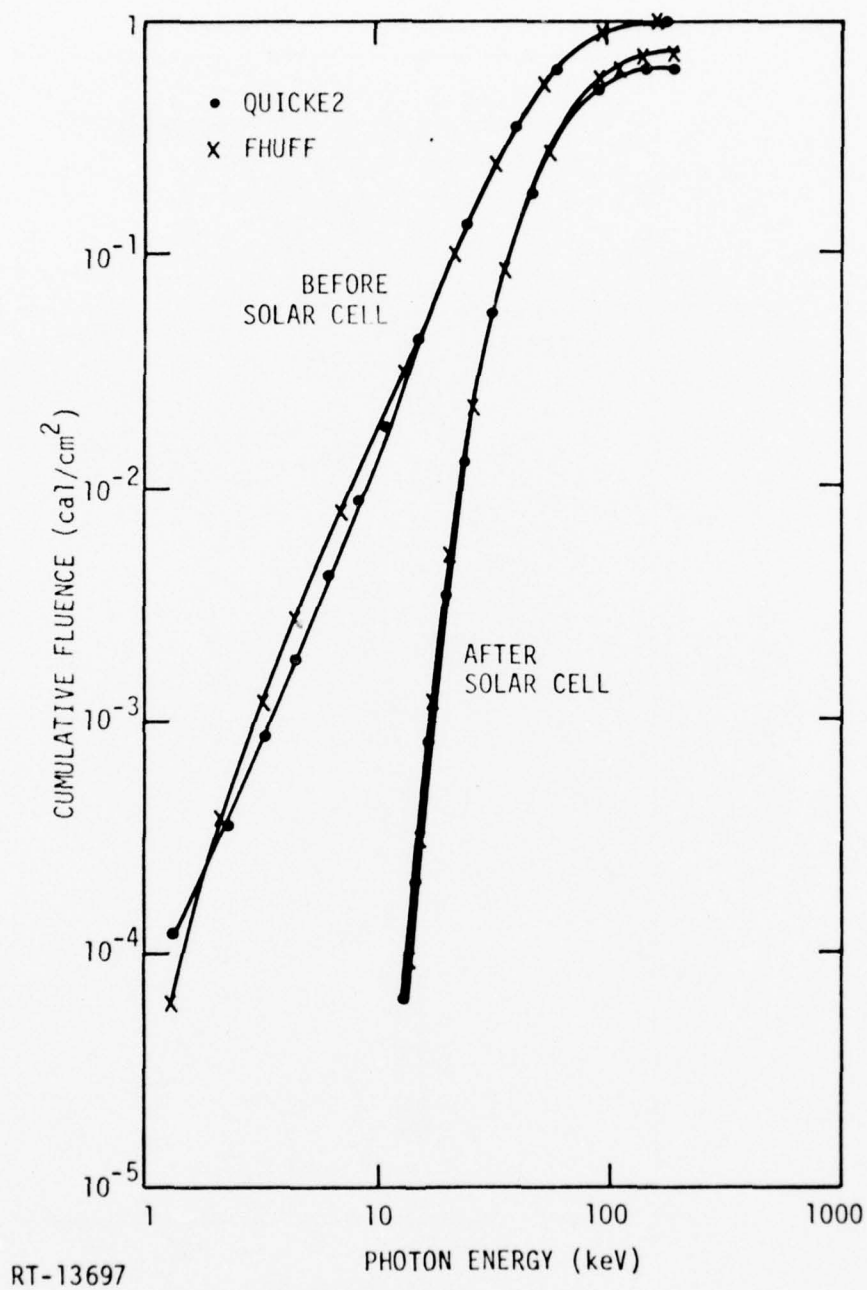
Figure 3-15. Comparison of QUICKE2 and FHUFF 15-keV blackbody photon spectra attenuated by solar cell and 30 mils of Aℓ

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Figure 3-16.   QUICKE2 and experimental results of Ebert and
Lauzon compared for forward-emission electron
angular distributions due to 1.25-MeV photons
incident on C

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Figure 3-17. QUICKE2 and experimental results of Ebert and
Lauzon compared for forward-emission electron
angular distributions due to 1.25-MeV photons
incident on Aℓ

RT-13699

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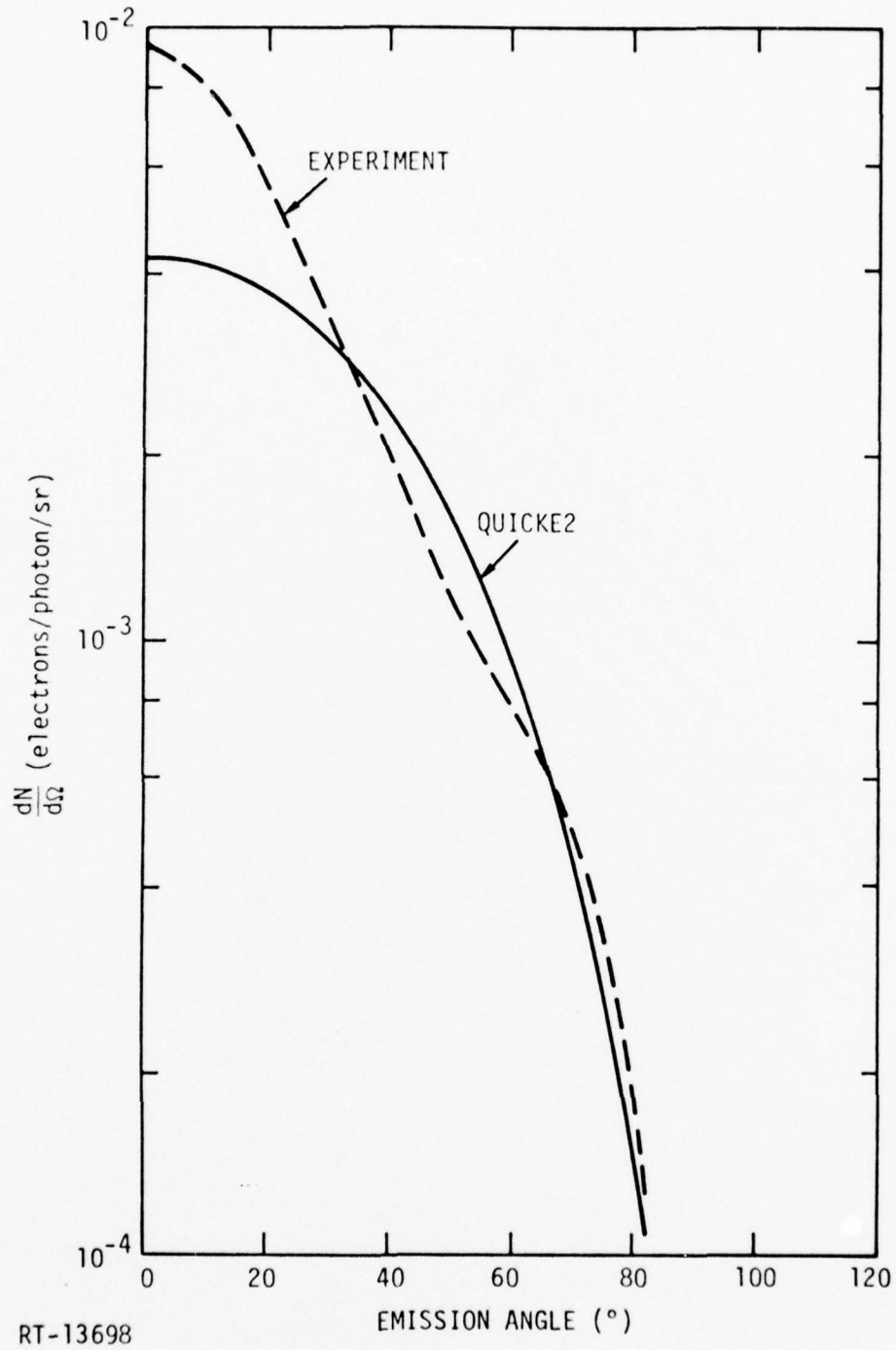Figure 3-18. QUICKE2 and experimental results of Ebert and Lauzon compared for forward-emission electron angular distributions due to 1.25-MeV photons incident on Cu
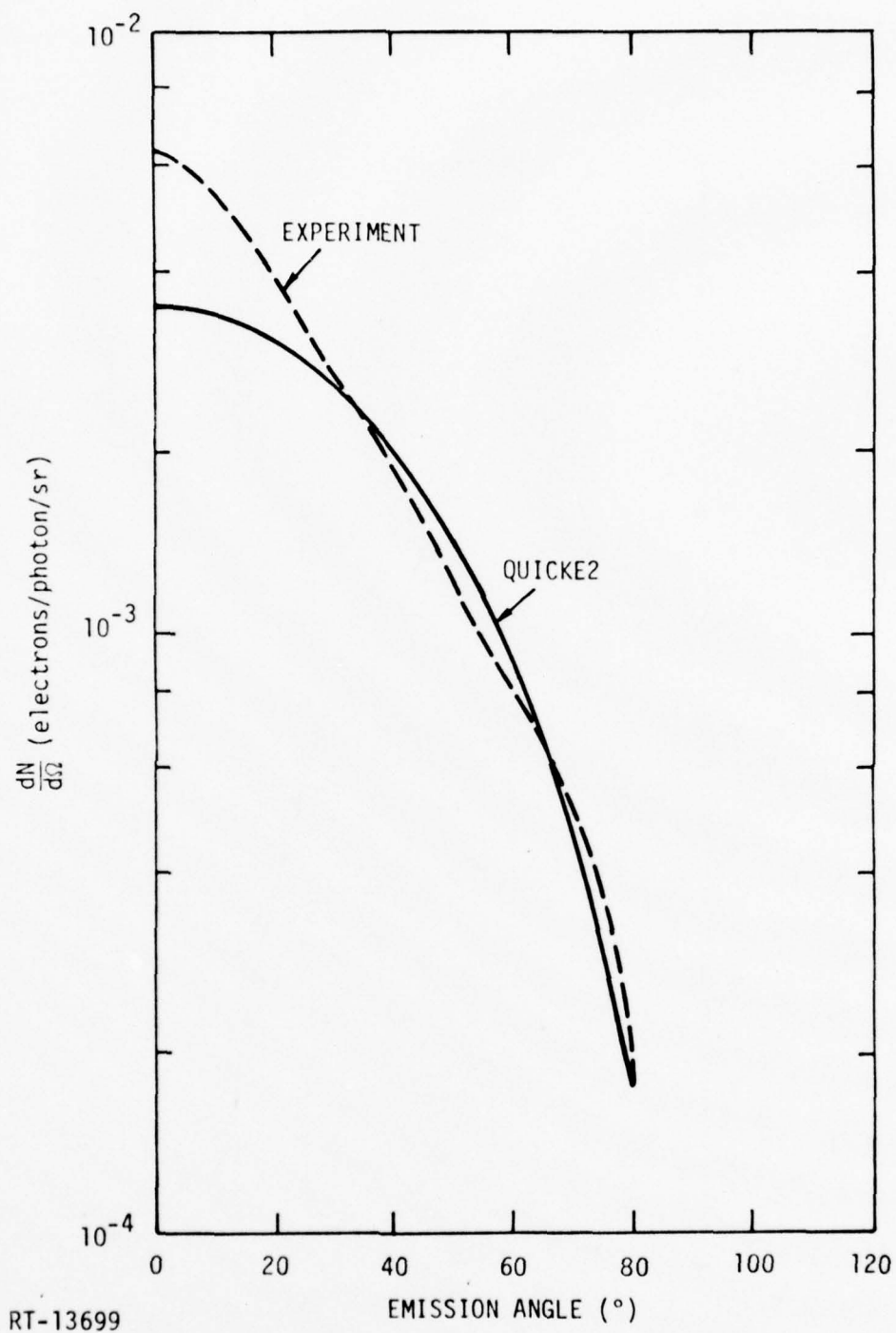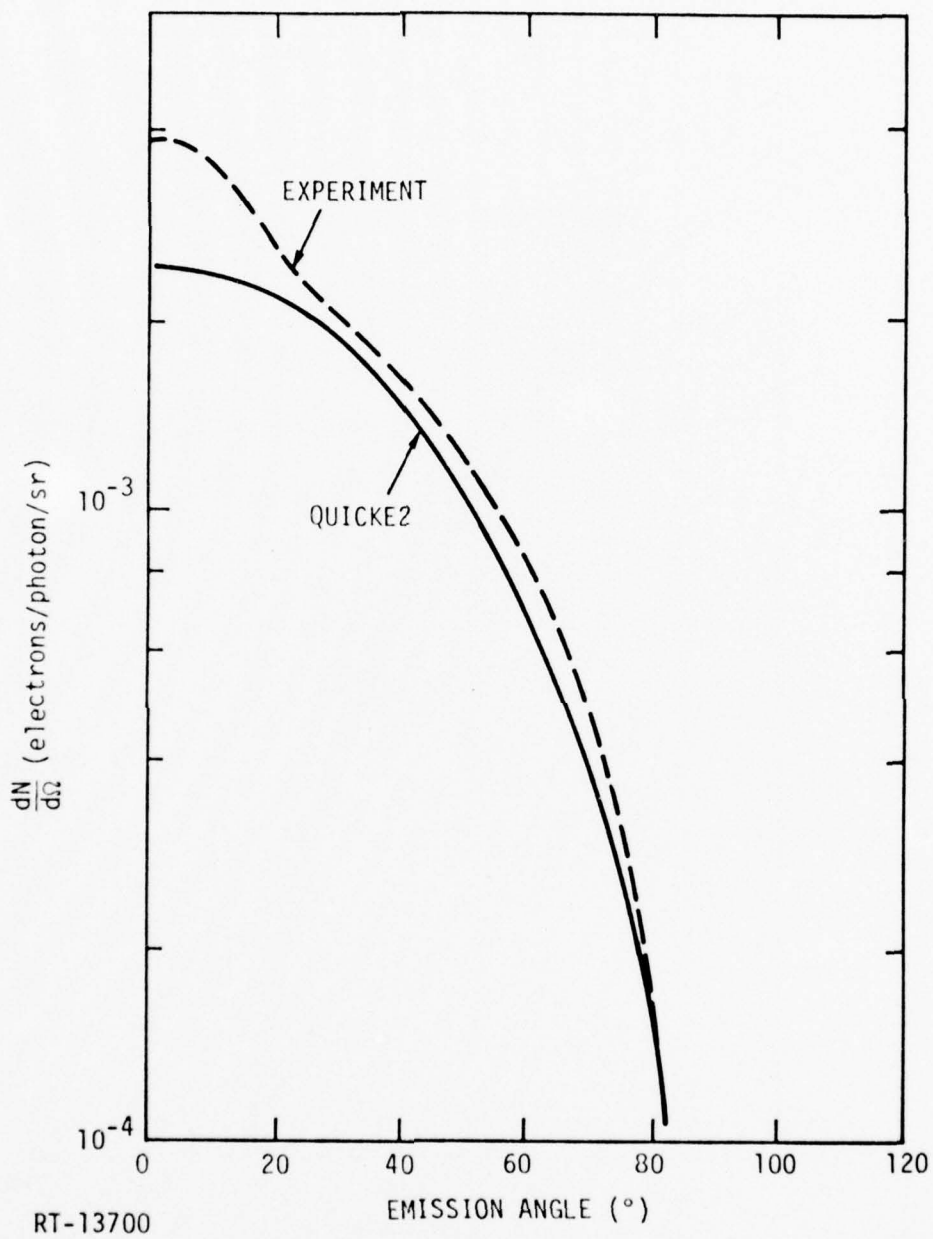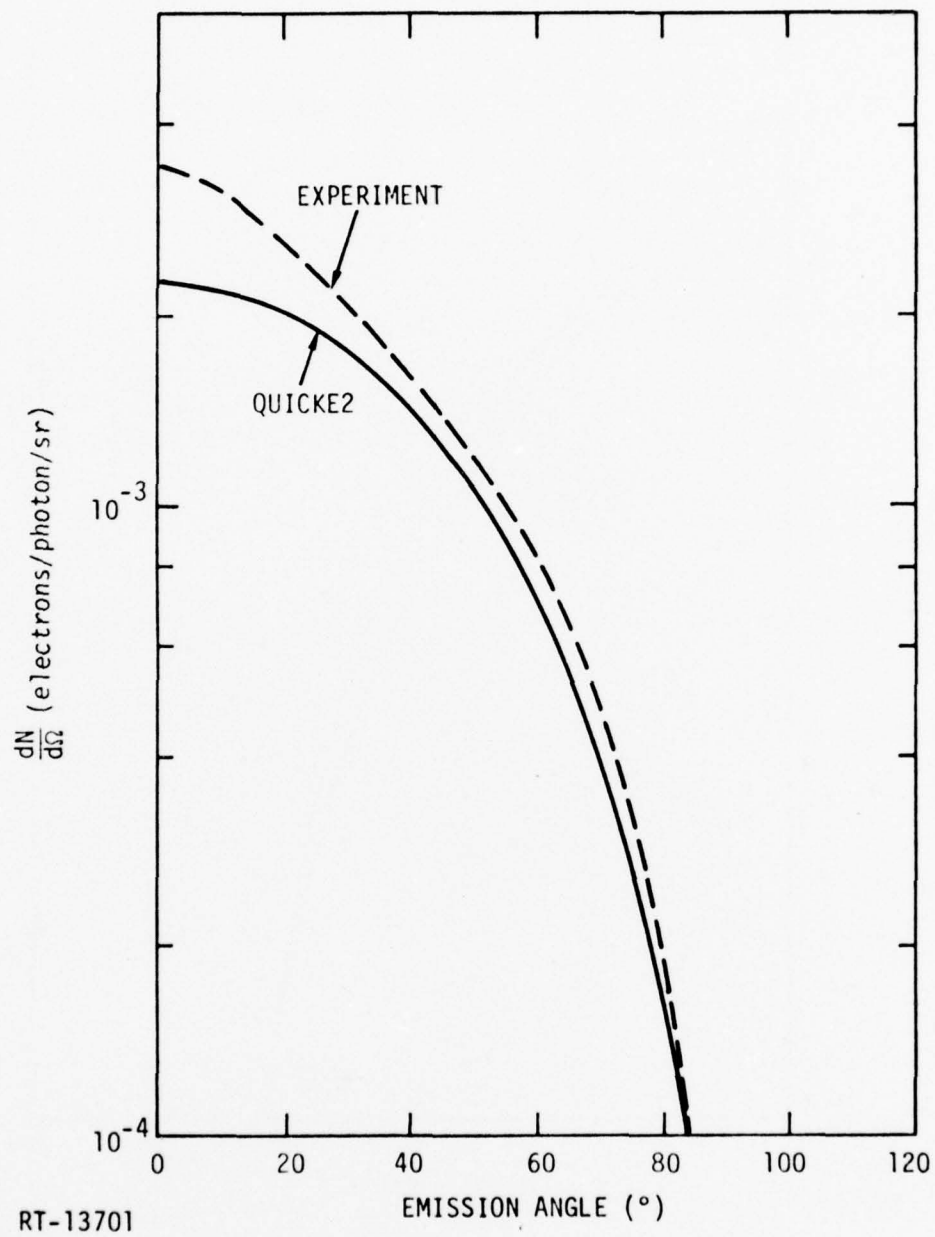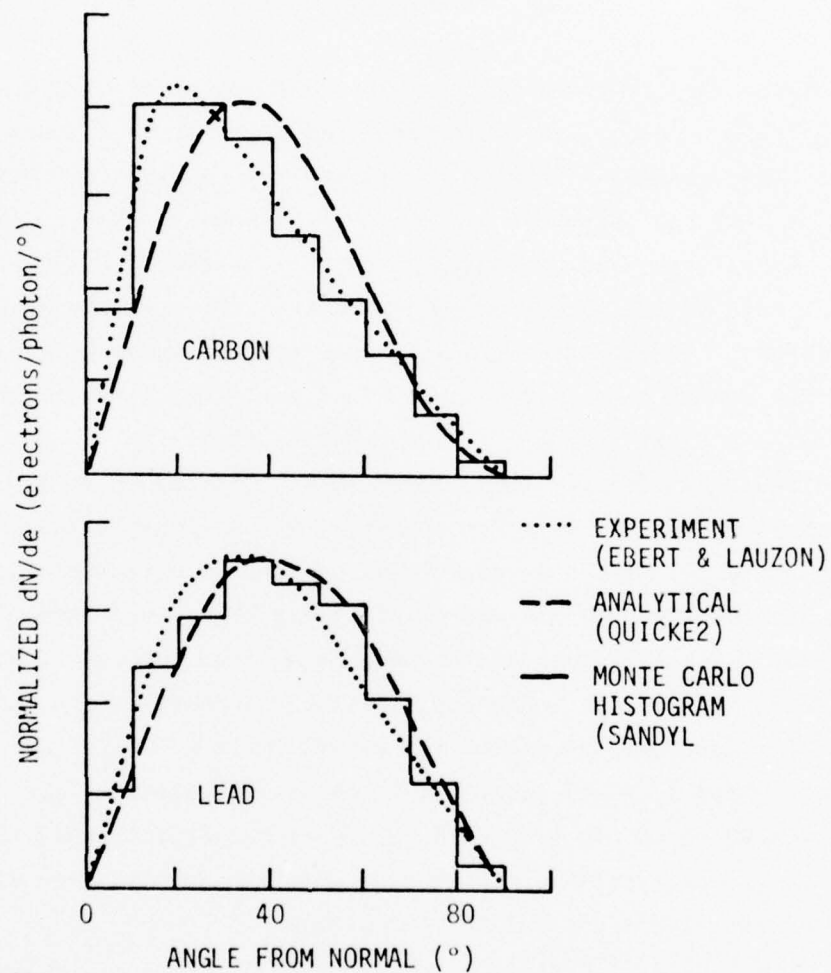
Figure 3-19. QUICKE2 and experimental results of Ebert and Lauzon compared for forward-emission electron angular distributions due to 1.25-MeV photons incident on Pb

Figure 3-20. Normalized angular distributions of electrons forward-emitted from C and Pb for Co^{60} radiation (from Ref 7)

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4. DESCRIPTION OF THE INPUTS

Detailed descriptions of the input cards required by QUICKE2 are given in this section. Variable names and physical or calculational significance are given, as well as the format for reading them into the code. Most of the variables are in NAMELIST format. These are specified in free form, separated by commas. The only restrictions are to begin the list with b$NAME, leave column 1 blank on all cards, and end the list with b$bEND. "b" indicates a blank space (necessary only in column 1) and "NAME" is the name of the NAMELIST given in the variable descriptions (see Figure 5-1 for a sample of the input deck).

In the input descriptions, arrays are indicated by an index following the variable name. If no index appears, only a single value is read in for the variable. The code counts the numbers of variables in cases where arrays are involved, so the number of values being read in need not be specified. Default values and maximum or minimum numbers of values are given where appropriate. Elements available in QUICKE2 are listed in Table 4-1. Elements not listed can be referenced.

The IOPT(27) option described in the table causes a file of data to be written which can be treated directly by the PLOTALL code (Ref. 11). This permits the overlay of photon and electron spectra from different plates or from different QUICKE2 calculations.

11. A. J. Woods, T. N. Delmer, and M. A. Chipman, "The Arbitrary Body of Revolution (ABORC) Code for SGEMP/IEMP," INTEL-RT 8141-028, April 1976.

Card Type	Variable Name and Description	Format
1	Title card (colums 1-72)	12A6
2	ECALC(I) - electron emission energies in MeV. Minimum ECALC is 0.001 MeV. Up to 34 values. Calculated from photon energies if not read in.	NAMELIST/SPECTRA/
2	HVSPECT(I) - energies in MeV for photon spectrum. Up to 50 values. Omit for blackbody spectrum.	NAMELIST/SPECTRA/
2	DNDESP(I) - relative intensities (energy/energy or number/energy according to NSPECT) of photon spectrum. Up to 50 values. Omit for blackbody spectrum.	NAMELIST/SPECTRA/
2	KBT = 0 (default) if an arbitrary spectrum is input > 0 to generate an incident blackbody spectrum with a temperature of KBT keV.	NAMELIST/SPECTRA/
2	IOPT(I): 40 values IOPT(26) = 1 to punch all emission electron energy distributions on cards in free-field format (default = 0) IOPT(27) = 1 to put photon and electron spectra on file TAPE7 for treatment by PLOTALL (default = 1)	NAMELIST/SPECTRA/
2	NSPECT = 0 (default) for DNDESP(I) in energy/energy = -1 for DNDESP(I) in number/energy	NAMELIST/SPECTRA/
3	INDEXX-QUICKE2 internal table number for test detector element for dose calculation. Must specify an element from Table 4-1. WARNING: DO NOT USE ATOMIC NUMBERS HERE. SPECIFY THE APPROPRIATE NUMBER FROM THE COLUMN LABELED "INTERNAL NUMBER" IN TABLE 4-1.	I5 (columns 1-5)

NOTE: Must input separate NAMELIST/PLATE/ cards for each plate. There is no limit on the number of plates.

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Card Type	Variable Name and Description	Format
4	NPCT = 0 (default) for plate elements in fraction by number = 1 for plate elements in fraction by weight	NAMELIST/PLATE/
4	IPRINT = 0 (default) no cross-section print = 1 to print cross sections from input tape	NAMELIST/PLATE/
4	KOPT = 0 (default) = 1 to print detailed information about electron production by photons	NAMELIST/PLATE/
4	NTYPE = 0 (default) = 1 to calculate bulk current at forward edge of plate	NAMELIST/PLATE/
4	NEL(I): atomic numbers of elements comprising plate. See Table 4-1. Maximum number = 8 per plate.	NAMELIST/PLATE/
4	F(I): respective fractions of elements (see NPCT). Default = 1. Maximum number = 8 per plate.	NAMELIST/PLATE/
4	IOPT(I): 40 values. No values need to be read in here at present.	NAMELIST/PLATE/
4	IEM = 0 no emission from plate = 1 forward emission from plate (default) = 2 reverse emission from plate = 3 forward and reverse emission from plate	NAMELIST/PLATE/
4	TAU: thickness of plate in g/cm^2	NAMELIST/PLATE/
4	HVDEG: angle in degrees between surface normal of plate and direction of photon beam. Default = 0. WARNING: THIS ANGLE IS NOT INCLUDED IN PHOTON ATTENUATION CALCULATION. ALSO, WHEN NON-ZERO VALUE IS USED, RESULTING ELECTRON YIELDS ARE GIVEN IN UNITS OF C/cm^2 NORMAL TO MATERIAL SURFACE PER cal/cm^2 PERPENDICULAR TO PHOTON BEAM.	NAMELIST/PLATE/
4	QUIT = 0 (default) = 1 signifies last plate	NAMELIST/PLATE/
4	DENSITY: density of plate (g/cm^3)	NAMELIST/PLATE/

Table 4-1

ELEMENTS AVAILABLE IN QUICKE2

Atomic Number (Z)	Internal Number	Name
1	1	Hydrogen
4	2	Beryllium
6	3	Carbon
7	4	Nitrogen
8	5	Oxygen
9	6	Fluoride
12	7	Magnesium
13	8	Aluminum
14	9	Silicon
17	10	Chlorine
18	11	Argon
20	12	Calcium
22	13	Titanium
26	14	Iron
28	15	Nickel
29	16	Copper
32	17	Germanium
41	18	Niobium
47	19	Silver
50	20	Tin
60	21	Neodymium
73	22	Tantalum
79	23	Gold
82	24	Lead
92	25	Uranium

5. SAMPLE PROBLEM AND OUTPUT DESCRIPTION

The QUICKE2 output is best illustrated by sample problems. Sample
calculations are discussed here, giving the physical and calculational
significances of the major quantities.

The first problem involves the emission generated when a 15-keV
blackbody photon spectrum is incident on 40 mils of Aℓ. The input card
images for this problem are as shown in Figure 5-1, and the output as in
Figure 5-2. On the first page of output is the title, followed below by
a description of the first material, or "plate," since the problem is one-
dimensional. This description gives the number of elements in the mate-
rial and the name, fraction by number, and atomic number of each element.
The data file location where the cross sections for each element are
stored is given (here, "8" indicates that the information for Aℓ is stored
on file 8 of the data tape), and the thickness of the material is printed.
The quantity labeled "input fluence" is simply a convenience output of the
code. It gives the total fluence in cal/cm^2 of the photon spectrum as
input to the code. The code renormalizes this fluence to 1 cal/cm^2.

An important point regarding QUICKE2 output should be understood when
interpreting results from other than normally incident photon beams. Quan-
tities given in terms of unit area differ in definition, depending on
whether they pertain to photons or electrons. Photon densities are always
per unit area perpendicular to the beam, whereas electron densities are
always per unit area perpendicular to the surface. Thus, for a non-normal
incidence problem, the correct yield is obtained by simply emitting the
number of electrons per unit area on the skewed surface obtained directly
from QUICKE2 and, of course, multiplying by the fluence in cal/cm^2 perpen-
dicular to the photon beam.

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```
15BB,AL REV
SSPECTRA KBT=15, ECALC=   .001,.0012,.0014,.0016,.0018,.002,.0022,.0025,
.0035,.0045,.0055,.0065,.0075,.0085,.0095,.0125,.0175,.0225,.0275,.0325,.0375,
.045,.055,.07,.09,.105,.11,.12,.13,.14,.15,.16,.17,.18,$END
i
SPLATE NEL=13, TAU=.272,IEM=3,QUIT=1., DENSITY=1.,  $END
```

Figure 5-1.   QUICKE2 sample problem input for 15-keV blackbody spectrum
incident on a 40-mil Al plate causing both forward and
reverse electron emission

15BH,AL KEV

PLATE   NO. OF ELEMENTS   ELEMENT   FRACTION BY NO.   ATOMIC NO.   ELEMENT NO.   THICKNESS(GM/CM2)
  1   1   ALUMINUM   1.0000   13   8   2.72E-01

INPUT FLUENCE= 9.729E-02 CAL/CM2

FLUX SPECTRUM INCIDENT ON PLATE 1

POINT	ENERGY (MEV)	FLUX (CAL/CM**2/MEV)	CUMULATIVE FLUX (CAL/CM**2)	POINT	ENERGY (MEV)	FLUX (CAL/CM**2/MEV)	CUMULATIVE FLUX (CAL/CM**2)

TOTAL ENERGY CONTENT OF SPECTRUM IS 1.000E+00 CAL/CM2.

AVERAGE PHOTON ENERGY IS 4.050E-02 MEV

TOTAL NUMBER OF PHOTONS IS 6.445E+19

Figure 5-2. Sample problem output for 15-keV blackbody spectrum
incident on 40 mils of Aℓ

REVERSE YIELD FROM PLATE   1 IS 4.228E-08 COULOMBS/ (CAL INCIDENT ON PLATE 1).
THE CORRESPONDING EMISSION CURRENT FOR A 10 NSEC FWHM PULSE IS 4.228E+00 AMPS/(CAL INCIDENT ON PLATE 1)
THE VALUES PER CAL INCIDENT ON PLATE   1 ARE 4.228E-08 COULOMBS/CAL AND 4.228E+00 AMPS/CAL,RESPECTIVELY.

REVERSE-EMITTED ELECTRON ANGULAR DISTRIBUTION INTEGRATED OVER ENERGY

ANGLE(DEGREES)	ELECTRONS/CAL/DEG.	ELECTRONS/CAL/STERAD.	NUMBER .GT. A	A(DEGREES)
180.0	0.	6.962E+10	2.577E+11	175.0
170.0	1.326E+09	6.964E+10	2.577E+11	165.0
160.0	2.601E+09	6.954E+10	2.444E+11	155.0
150.0	3.714E+09	6.774E+10	2.184E+11	145.0
140.0	4.485E+09	6.562E+10	1.815E+11	135.0
130.0	4.706E+09	5.602E+10	1.364E+11	125.0
120.0	4.242E+09	4.467E+10	8.937E+10	115.0
110.0	3.120E+09	3.028E+10	4.695E+10	105.0
100.0	1.574E+09	1.458E+10	1.574E+10	95.0
90.0	-1.094E+04	-9.980E+04	-1.094E+05	85.0

REVERSE-EMITTED ELECTRON ENERGY DISTRIBUTION INTEGRATED OVER ANGLE

ENERGY (MEV)	TOTAL	PER BIN	NUMBER/MEV	MIDPOINT (MEV)
9.0000000E-04	2.4551628E+11	9.2011421E+09	4.6005710E+13	1.0000000E-03
1.1000000E-03	2.3631514E+11	1.0662030E+10	5.3310149E+13	1.2000000E-03
1.3000000E-03	2.2565311E+11	1.2155675E+10	6.0768374E+13	1.4000000E-03
1.5000000E-03	2.1349943E+11	2.6562437E+09	1.3281218E+13	1.6000000E-03
1.7000000E-03	2.1084319E+11	2.9487024E+09	1.4743512E+13	1.8000000E-03
1.9000000E-03	2.0789449E+11	3.2379402E+09	1.6189701E+13	2.0000000E-03
2.1000000E-03	2.0465655E+11	4.4317494E+09	1.7126994E+13	2.2000000E-03
2.3500000E-03	2.0022480E+11	1.5000835E+10	2.0001285E+13	2.5000000E-03
3.0000000E-03	1.8723967E+11	1.5294187E+10	1.5294187E+13	3.5000000E-03
4.0000000E-03	1.7192577E+11	1.2400960E+10	1.2400960E+13	4.5000000E-03
5.0000000E-03	1.5952481E+11	1.5153185E+10	1.5153185E+13	5.5000000E-03
6.0000000E-03	1.4439163E+11	1.2115728E+10	1.2115728E+13	6.5000000E-03
7.0000000E-03	1.3227590E+11	1.0003941E+10	1.0003941E+13	7.5000000E-03
8.0000000E-03	1.2227196E+11	1.1318334E+10	1.1318334E+13	8.5000000E-03
9.0000000E-03	1.1095362E+11	1.8598088E+10	9.2990440E+12	9.5000000E-03
1.1000000E-02	9.2355540E+10	2.8614277E+10	7.1535627E+12	1.2500000E-02
1.5000000E-02	5.3741263E+10	2.2232646E+10	4.4465291E+12	1.7500000E-02
2.0000000E-02	4.1508617E+10	1.2793904E+10	2.5587809E+12	2.2500000E-02
2.5000000E-02	2.8714712E+10	1.0119979E+10	2.0239958E+12	2.7500000E-02
3.0000000E-02	1.8594733E+10	6.1700914E+09	1.2340183E+12	3.2500000E-02
3.5000000E-02	1.2424642E+10	4.6788491E+09	7.4830385E+11	3.7500000E-02
4.1250000E-02	7.7477428E+09	3.9536284E+09	4.9557539E+11	4.5000000E-02
5.0000000E-02	3.8141143E+09	2.6450454E+09	2.1160363E+11	5.5000000E-02
6.2500000E-02	1.1690089E+09	9.1577207E+08	5.2329852E+10	7.0000000E-02
8.0000000E-02	2.5329683E+08	1.8928715E+08	1.0816407E+10	9.0000000E-02
9.7500000E-02	6.4009695E+07	3.1805780E+07	3.1805780E+09	1.0500000E-01
1.0750000E-01	3.2205915E+07	1.6874718E+07	2.2499704E+09	1.1000000E-01
1.1500000E-01	1.5329136E+07	8.3315280E+06	8.3315280E+08	1.2000000E-01
1.2500000E-01	6.4976807E+06	4.0805795E+06	4.0805795E+08	1.3000000E-01
1.3500000E-01	2.9172295E+06	1.9203767E+06	1.9203767E+08	1.4000000E-01
1.4500000E-01	9.9685278E+05	6.5241907E+05	6.5241907E+07	1.5000000E-01
1.5500000E-01	3.6443371E+05	2.6557703E+05	2.6557703E+07	1.6000000E-01
1.6500000E-01	1.0055668E+05	8.8472255E+04	8.8472255E+06	1.7000000E-01
1.7500000E-01	1.2384444E+04	1.2384443E+04	1.2384443E+06	1.8000000E-01

AVERAGE ELECTRON ENERGY IS 1.147E-02 MEV, TOTAL EMITTED CHARGE IS 5.928E-08 COULOMBS/CAL ON PLATE 1
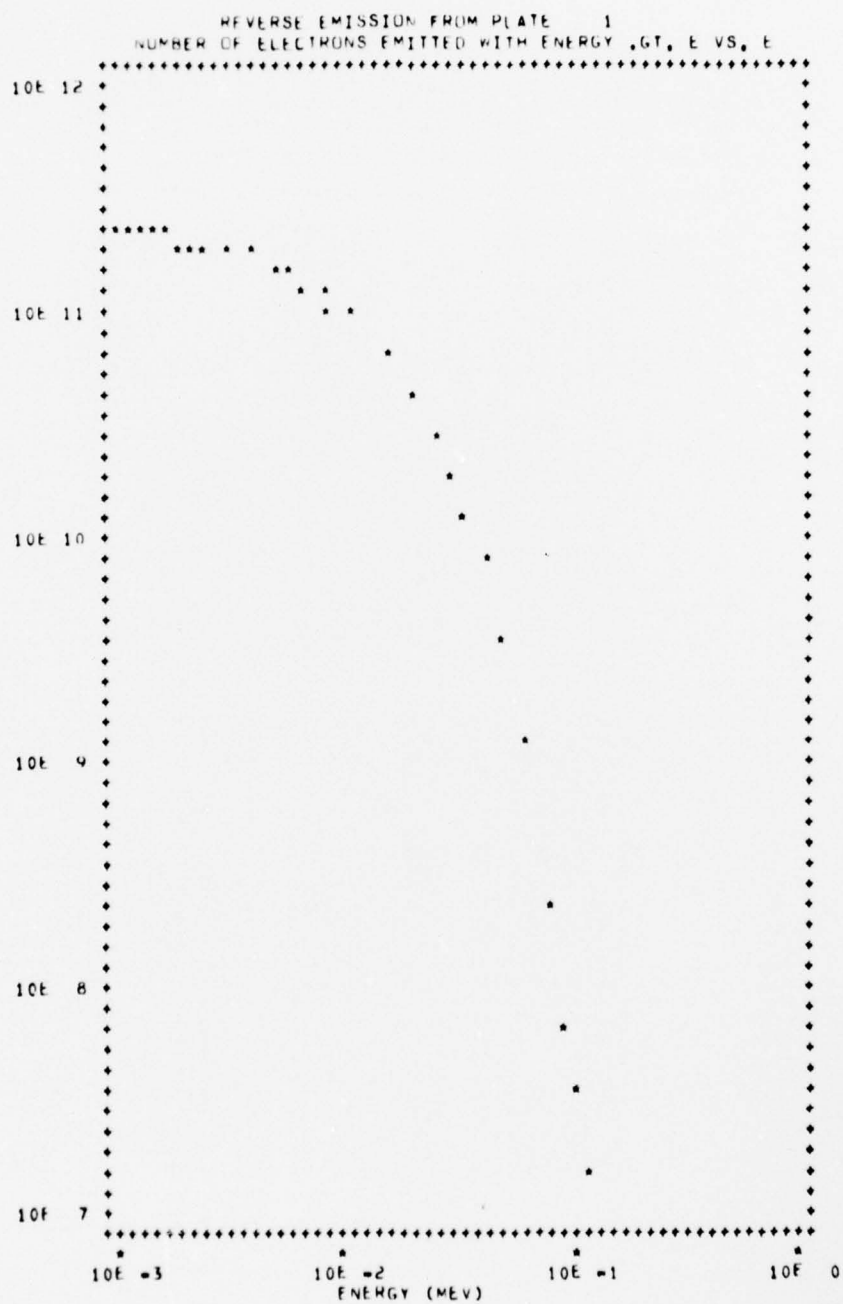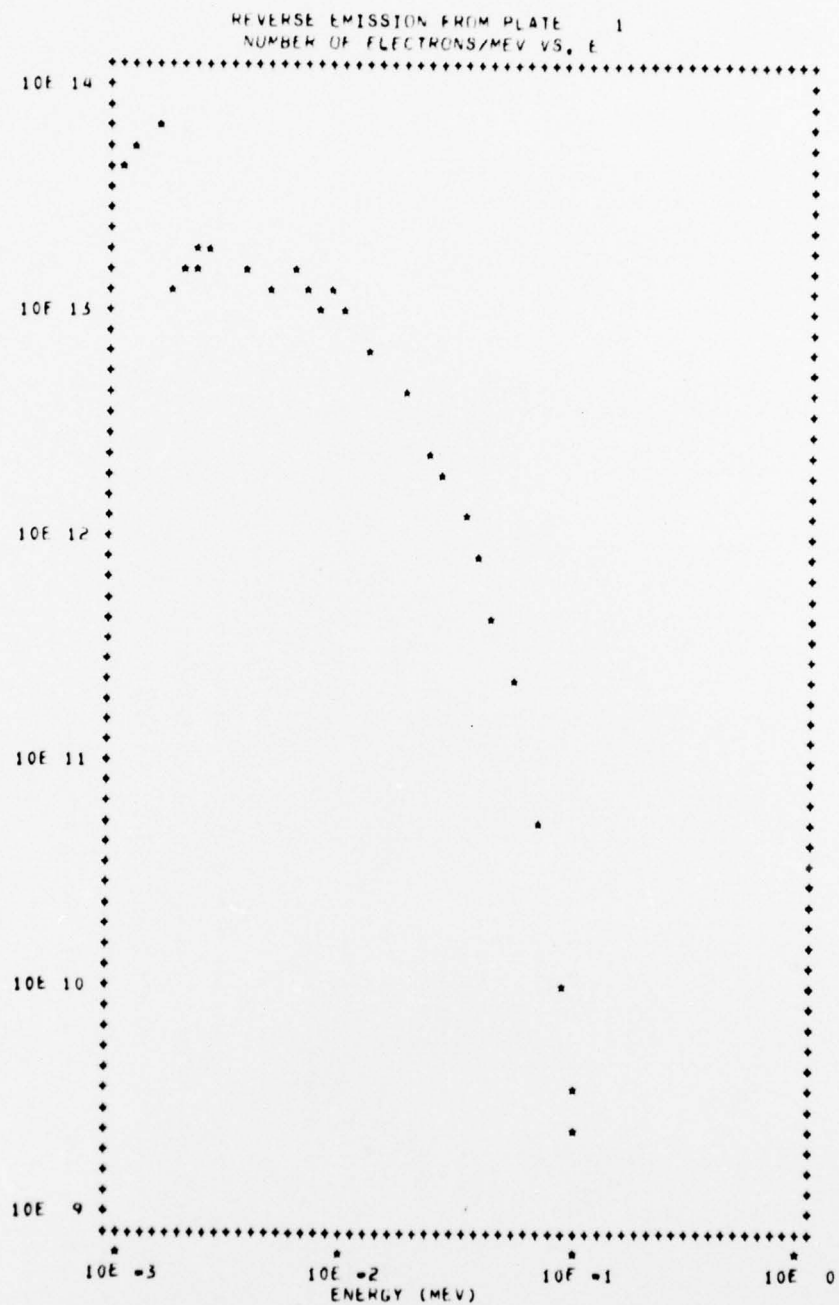
Figure 5-2 (cont.)

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Figure 5-2 (cont.)

Figure 5-2 (cont.)

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FLUX SPECTRUM INCIDENT ON PLATE 2

POINT	ENERGY (MEV)	FLUX (CAL/CM**2/MEV)	CUMULATIVE FLUX (CAL/CM**2)
1	1.500E-05	3.784006E-49	5.676130E-52
2	3.500E-05	5.040040E-45	5.676130E-52
3	9.500E-05	9.059100E-31	6.084770E-34
4	6.000E-05	6.054830E-14	9.082245E-17
5	7.500E-05	7.067532E-07	2.950999E-10
6	9.000E-05	2.026107E-04	3.042231E-07
7	1.050E-02	8.105634E-03	1.242268E-05
8	1.200E-02	7.079947E-02	1.386623E-04
9	1.350E-02	2.793409E-02	5.373366E-04
10	1.500E-02	7.034488E-01	2.120493E-03
11	1.600E-02	2.164414E+00	8.613735E-03
12	1.800E-02	4.067199E+00	2.087535E-02
13	2.400E-02	6.053598E+00	3.905553E-02
14	2.700E-02	7.847701E+00	6.209841E-02
15	3.000E-02	9.474292E+00	9.112169E-02
16	3.300E-02	1.064700E+01	1.218127E-01
17	3.600E-02	1.162529E+01	1.505056E-01
18	3.900E-02	1.230322E+01	1.949082E-01
19	4.200E-02	1.289572E+01	2.330554E-01
20	4.500E-02	1.286779E+01	2.710587E-01
21	4.800E-02	1.284342E+01	3.019302E-01
22	5.100E-02	1.260305E+01	3.441795E-01
23	5.400E-02	1.234005E+01	3.851826E-01
24	5.700E-02	1.190127E+01	4.204860E-01
25	6.000E-02	1.134430E+01	4.593040E-01

POINT	ENERGY (MEV)	FLUX (CAL/CM**2/MEV)	CUMULATIVE FLUX (CAL/CM**2)
26	6.375E-02	1.084525E+01	4.942245E-01
27	6.750E-02	9.854371E+00	5.361222E-01
28	7.125E-02	9.035618E+00	5.700657E-01
29	7.500E-02	8.220992E+00	6.008930E-01
30	7.875E-02	7.422539E+00	6.287275E-01
31	8.250E-02	6.654504E+00	6.536779E-01
32	8.625E-02	5.926025E+00	6.759005E-01
33	9.000E-02	5.241790E+00	6.958612E-01
34	9.375E-02	4.624005E+00	7.129227E-01
35	9.750E-02	4.052210E+00	7.281298E-01
36	1.013E-01	3.539005E+00	7.410335E-01
37	1.050E-01	3.076790E+00	7.529435E-01
38	1.088E-01	2.665525E+00	7.622265E-01
39	1.125E-01	2.297110E+00	7.715665E-01
40	1.163E-01	1.975794E+00	7.792585E-01
41	1.200E-01	1.693685E+00	7.844005E-01
42	1.275E-01	1.235980E+00	7.977325E-01
43	1.350E-01	8.492335E-01	8.044017E-01
44	1.425E-01	8.350495E-01	8.091045E-01
45	1.500E-01	4.497010E-01	8.125555E-01
46	1.575E-01	3.100715E-01	8.149005E-01
47	1.650E-01	2.201355E-01	8.165505E-01
48	1.725E-01	1.527900E-01	8.177028E-01
49	1.800E-01	1.052105E-01	8.184215E-01
50	1.875E-01	7.230356E-02	8.190365E-01

TOTAL ENERGY CONTENT OF SPECTRUM IS 8.190E-01 CAL/CM2.

AVERAGE PHOTON ENERGY IS 5.079E-02 MEV

TOTAL NUMBER OF PHOTONS IS 4.204E+14

DOSE IN SILICON DETECTOR AT FRONT END OF PLATE 1 = 1.26025E+06

DOSE IN SILICON DETECTOR AT BACK END OF PLATE 1 = 2.23415E+05

DOSE IN CARBON DETECTOR AT FRONT END OF PLATE 1 = 1.96511E+05

DOSE IN CARBON DETECTOR AT BACK END OF PLATE 1 = 6.08855E+04

DOSE IN MATERIAL AT FRONT END OF PLATE 1 = 9.96440E+05

DOSE IN MATERIAL AT BACK END OF PLATE 1 = 1.83090E+05

AVERAGE DOSE IN LAYER 1 = 2.78102E+05

DOSE IN HYDROGEN TEST DETECTOR AT FRONT END OF PLATE 1 = 1.38892E+05

DOSE IN HYDROGEN TEST DETECTOR AT BACK END OF PLATE 1 = 1.11755E+05

Figure 5-2 (cont.)

FORWARD YIELD FROM PLATE   1 IS 2.215E-08 COULOMBS/ (CAL INCIDENT ON PLATE 1).
THE CORRESPONDING EMISSION CURRENT FOR A 10 NSEC FWHM PULSE IS 2.215E+00 AMPS/(CAL INCIDENT ON PLATE 1)
THE VALUES PER CAL INCIDENT ON PLATE   2 ARE 2.705E-08 COULOMBS/CAL AND 2.705E+00 AMPS/CAL,RESPECTIVELY.

FORWARD-EMITTED ELECTRON ANGULAR DISTRIBUTION INTEGRATED OVER ENERGY

ANGLE(DEGREES)	ELECTRONS/CAL/DEG.	ELECTRONS/CAL/STERAD.	NUMBER .GT. A	A(DEGREES)
0.	0.	4.775E+10	7.422E+10	0.
10.0	3.918E+08	2.058E+10	7.422E+10	5.0
20.0	7.642E+08	2.037E+10	7.030E+10	15.0
30.0	1.083E+09	1.975E+10	6.266E+10	25.0
40.0	1.297E+09	1.840E+10	5.183E+10	35.0
50.0	1.550E+09	1.607E+10	3.886E+10	45.0
60.0	1.209E+09	1.275E+10	2.536E+10	55.0
70.0	8.836E+08	8.575E+09	1.327E+10	65.0
80.0	4.436E+08	4.108E+09	4.436E+09	75.0
90.0	-5.071E+03	-2.800E+04	-5.071E+04	85.0

FORWARD-EMITTED ELECTRON ENERGY DISTRIBUTION INTEGRATED OVER ANGLE

ENERGY (MEV)	TOTAL	PER BIN	NUMBER/MEV	MIDPOINT (MEV)
9.0000000E-04	1.33117245E+11	2.50453060E+08	1.25226530E+12	1.00000000E-03
1.1000000E-03	1.32866789E+11	2.86809592E+08	1.43404696E+12	1.20000000E-03
1.3000000E-03	1.32579940E+11	3.23856871E+08	1.61928436E+12	1.40000000E-03
1.5000000E-03	1.32256123E+11	1.34046736E+08	6.70253678E+11	1.60000000E-03
1.7000000E-03	1.32122076E+11	1.45305730E+08	7.26528649E+11	1.80000000E-03
1.9000000E-03	1.31976771E+11	1.55514470E+08	7.77572352E+11	2.00000000E-03
2.1000000E-03	1.31821256E+11	2.07979558E+08	8.31918233E+11	2.20000000E-03
2.3500000E-03	1.31615277E+11	5.89952365E+08	9.07619023E+11	2.50000000E-03
3.0000000E-03	1.31023524E+11	1.16174275E+09	1.16174275E+12	3.50000000E-03
4.0000000E-03	1.29861582E+11	1.41491541E+09	1.41491541E+12	4.50000000E-03
5.0000000E-03	1.28446660E+11	1.67808062E+09	1.67808062E+12	5.50000000E-03
6.0000000E-03	1.26768586E+11	1.95572893E+09	1.95572893E+12	6.50000000E-03
7.0000000E-03	1.24812857E+11	2.25467221E+09	2.25467221E+12	7.50000000E-03
8.0000000E-03	1.22558184E+11	2.57478918E+09	2.57478918E+12	8.50000000E-03
9.0000000E-03	1.19983595E+11	5.80960315E+09	2.90480158E+12	9.50000000E-03
1.1000000E-02	1.14175792E+11	1.55125554E+10	5.87813884E+12	1.25000000E-02
1.5000000E-02	9.86612367E+10	2.20290453E+10	4.40592906E+12	1.75000000E-02
2.0000000E-02	7.66315915E+10	1.72427495E+10	3.44854990E+12	2.25000000E-02
2.5000000E-02	5.93888420E+10	1.66811352E+10	3.33622703E+12	2.75000000E-02
3.0000000E-02	4.27077066E+10	1.15879166E+10	2.31758356E+12	3.25000000E-02
3.5000000E-02	3.11197900E+10	9.52480075E+09	1.52460924E+12	3.75000000E-02
4.1250000E-02	2.15909823E+10	9.46301875E+09	1.08148785E+12	4.50000000E-02
5.0000000E-02	1.21279655E+10	7.72793182E+09	6.18234545E+11	5.50000000E-02
6.2500000E-02	4.40003171E+09	3.12408699E+09	1.78519371E+11	7.00000000E-02
8.0000000E-02	1.27594272E+09	8.68709718E+08	4.96405553E+10	9.00000000E-02
9.7500000E-02	4.07255006E+08	1.79287381E+08	1.79287381E+10	1.05000000E-01
1.0750000E-01	2.27945625E+08	1.06739211E+08	1.42318947E+10	1.10000000E-01
1.1500000E-01	1.21206415E+08	5.38075026E+07	5.38075026E+09	1.20000000E-01
1.2500000E-01	6.73989122E+07	3.33776688E+07	3.33776688E+09	1.30000000E-01
1.3500000E-01	3.40212434E+07	2.07056349E+07	2.07056349E+09	1.40000000E-01
1.4500000E-01	1.33156086E+07	6.64782838E+06	6.64782838E+08	1.50000000E-01
1.5500000E-01	6.61778021E+06	3.95851720E+06	3.95851720E+08	1.60000000E-01
1.6500000E-01	2.65926300E+06	2.24640888E+06	2.24640888E+08	1.70000000E-01
1.7500000E-01	4.12854124E+05	4.12854124E+05	4.12854124E+07	1.80000000E-01

AVERAGE ELECTRON ENERGY IS 2.617E-02 MEV. TOTAL EMITTED CHARGE IS 2.130E-08 COULOMBS/CAL ON PLATE 1

Figure 5-2 (cont.)

FORWARD EMISSION FROM PLATE   1
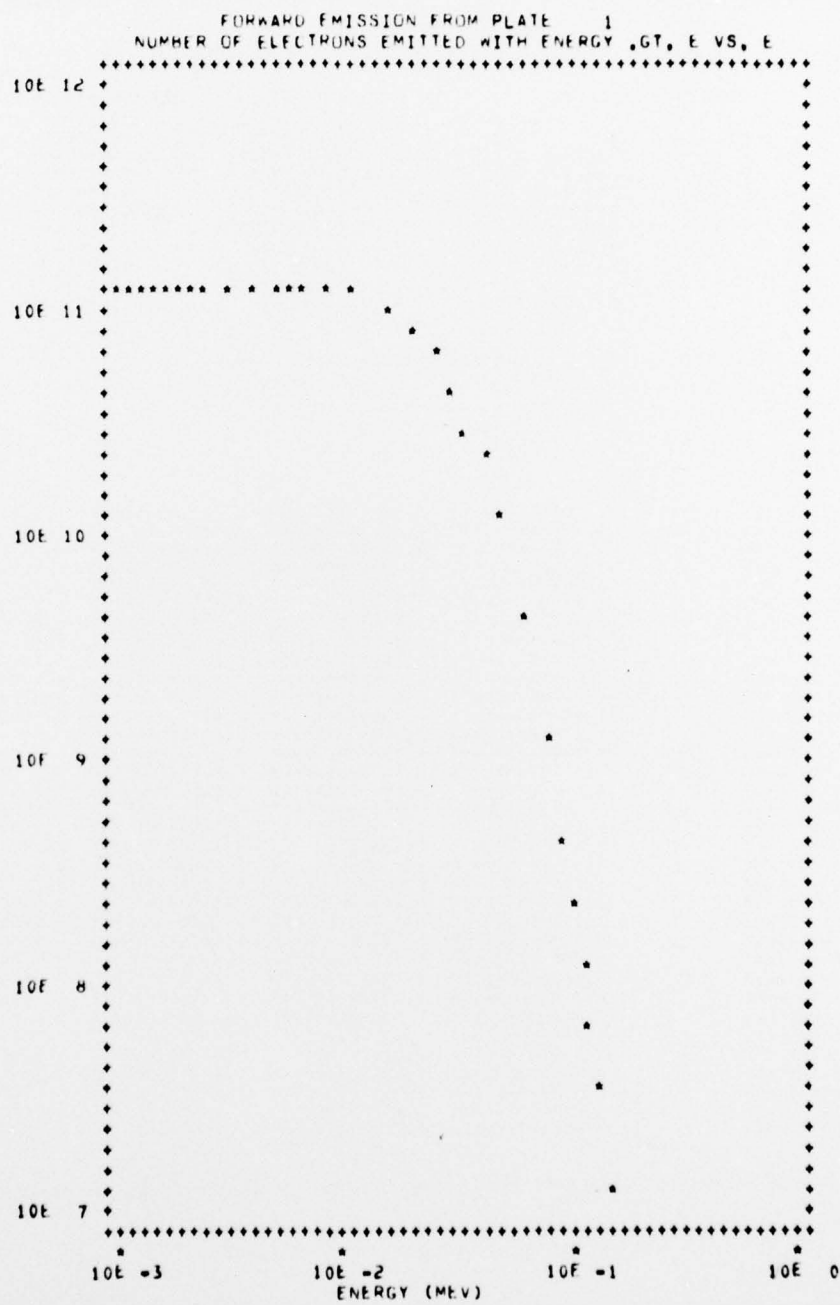NUMBER OF ELECTRONS EMITTED WITH ENERGY .GT. E VS. E
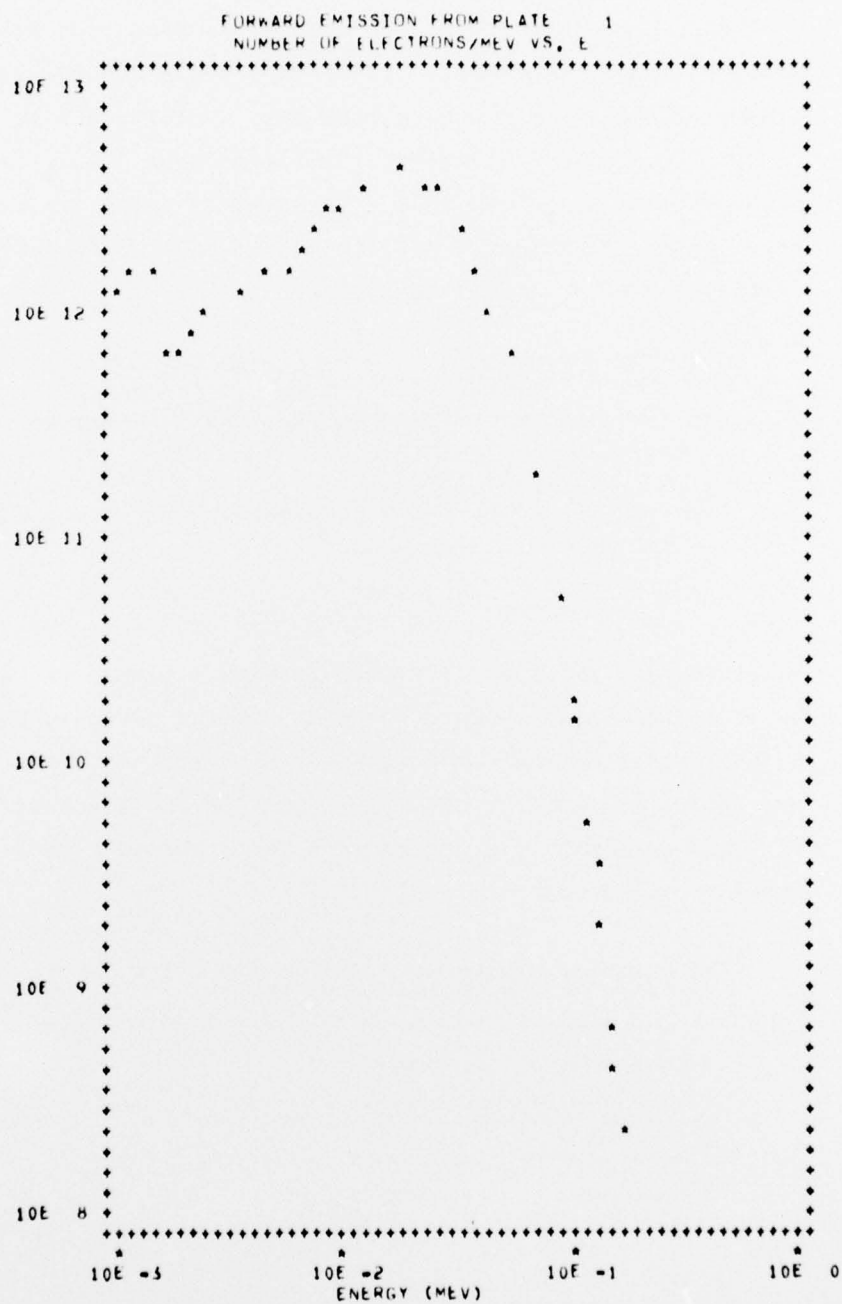
Figure 5-2 (cont.)

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Figure 5-2 (cont.)

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[When reverse emission only (emission code 2) or forward and reverse emission (emission code 3) is asked for from a plate, the bulk currents just inside the plate face closest to the source are printed out. Unfortunately, in some versions of the code, the plate index number for reverse emission is low by 1. In later versions, this error has been corrected and the legend says "Bulk currents in layer = ____ at entry face."]

```
BULK CURRENTS IN LAYER =      1 FOR EMISSION CODE =      1
BULK CURRENTS ALONG THE NORMAL DIRECTION

NET BULK CURRENTS ALONG THE NORMAL DIRECTION=    8.24140E-09

FORWARD CURRENT=    2.58326E-08

REVERSE CURRENT=    1.75912E-08
BULK CURRENTS PERPENDICULAR TO THE NORMAL DIRECTION

FORWARD CURRENT =    2.22836E-08

REVERSE CURRENT =    2.22836E-08
```

[When forward emission is requested from a plate, either by itself (emission code 1) or with reverse current, the bulk currents in the plate near the face farthest from the source are printed out. The layer index is correct. In later versions, the legend says "Bulk currents in layer = ____ at exit face."]

```
BULK CURRENTS IN LAYER =      0 FOR EMISSION CODE =      3
BULK CURRENTS ALONG THE NORMAL DIRECTION

NET BULK CURRENTS ALONG THE NORMAL DIRECTION=    1.66168E-08

FORWARD CURRENT=    7.32769E-08

REVERSE CURRENT=    5.66601E-08
BULK CURRENTS PERPENDICULAR TO THE NORMAL DIRECTION

FORWARD CURRENT =    6.79640E-08

REVERSE CURRENT =    6.79640E-08
```

Figure 5-2 (cont.)

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In the next section of output, the incident photon spectrum normalized to a total incident fluence of 1 cal/cm^2 is printed out, followed by the total energy content of the spectrum, the average photon energy, and the total number of photons/cm^2 corresponding to the total energy content. (Here, the total number of photons is 1 calorie's worth of photons with the spectral energy distribution indicated.) The average photon energy is taken as that energy, hν, which gives the total energy content when multiplied by the total number of incident photons. The total number of incident photons is useful in that results from other codes expressed in electrons/photon can easily be converted to coulombs/calorie by multiplying them by this total number and the electronic charge:

Yield in C/cal = yield in e/photon x (photon/cal) x (C/e) .

The next page of output contains electron emission information. The first line indicates the type of yield (here, reverse), the material number from which the electrons are being emitted (here, 1 indicates the first material), and the yield in C/cal incident on plate 1. This yield corresponds to the "quantum efficiency." The yields in C/cal incident on plate N are also provided in case the user is interested in the yield per calorie for a filtered spectrum.

Next, the breakdown of the electron emission into angular and energy distributions is given. The "emitted electron angular distribution integrated over energy" is meant to provide the angular distribution only roughly. The "emitted electron energy distribution integrated over angle" should be a more precise function, provided the energy bins are close enough together. This printout is derived from the "energy distribution" described in Section 2.2. The column TOTAL contains the number of electrons emitted with energies greater than the corresponding entry in the column ENERGY. The column PER BIN is the total number of electrons in a given energy bin bounded by the energies in the column ENERGY and centered on the corresponding energy in the column MIDPOINT. NUMBER/MEV is the number of electrons/MeV emitted at the corresponding energy under MIDPOINT. Printed below the energy distribution is the average electron energy (calculated in the same way as the average photon energy) and the total emitted charge. The latter number is the result of integrating the energy

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distribution dN/dE over energy. It should agree with the yield at the top of the page to within about 20 percent. Agreement is generally good except for back emission produced by low-energy photons (about 5 to 10 keV). In these cases, results should be used cautiously.

The next two pages are printer plots of TOTAL versus ENERGY and NUMBER/MEV versus MIDPOINT, described above. These plots are exactly the size of standard 5 x 3 log-log paper and may be xeroxed or used with a light table to save needless hours of hand-plotting.

The cycle repeats again with a printout of the photon spectrum emerging from the first material (and incident on the second). In the sample problem, the low-energy photons have been absorbed by the aluminum, reducing the total energy content from 1.0 to 0.82 cal/cm^2, raising the average photon energy from 40.5 to 50.8 keV, and reducing the total number of photons from 6.44 x 10^{14} to 4.21 x 10^{12} cm^{-2}.

Dose information is printed at this point. The energy depositions are in units of rads of the particular material indicated (1 rad = 100 erg/g). Silicon and carbon are always given, and a third material is specified in the inputs from among those available in QUICKE2 (see Table 4-1). Doses at the fronts and backs of the plates are given.

The forward electron emission results are in the same format as the reverse ones, but the spectrum used is that incident on the second material — i.e., the spectrum seen by all material within a few electron ranges of the emitting surface. The yield from plate 1 "per cal incident on plate 2" is higher than the yield from plate 1 "per cal incident on plate 1" since the latter number is calculated for a total spectral energy content of 0.82 cal/cm^2 - i.e., the energy remaining after the incident photons have been filtered through 40 mils of aluminum. The total yields at the top and bottom of the page agree to 4 percent, so in this sense, the results are trustworthy.

Bulk current information is also given. These currents are in units of electrons/cm^2-sec, photons/cm^2-sec, or electrons/photon. They pertain to regions greater than the largest electron range away from any interface. The quantities are described in some detail in Section 2.

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Finally, for extra information, there are two printing options. If the parameter KOPT is set to 1 (see Section 4), the code will generate the original QUICKE2 output. If IPRINT is set to 1, information from the data tape will be printed. Information on these printouts is available in Reference 1.

6. QUICKE2 COMPUTER REQUIREMENTS

QUICKE2 is a FORTRAN IV computer program of approximately 2000 cards in length, operational on a CDC 7600 computer. No machine language is employed. The code requires a tape containing the tabulation of a considerable amount of data for material properties for the 25 elements available. This file is about 300,000 numbers in length.

One additional file is also required for plot information. Memory requirements are about $34,000_{10}$ words of small core and no large core.

Typical run times are about 20 sec CDC 7600 time per electron emission spectrum. No additional computer programs are required by QUICKE2, but the PLOTALL code (Ref. 11) is very helpful in analyzing results of QUICKE2 calculations.

A present idiosyncrasy of the QUICKE2 version described here is that it is restricted to the CDC FTN FORTRAN extended compiler, version 1. Minor programming features do not permit its use on the more up-to-date FTN4 compiler available currently.

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